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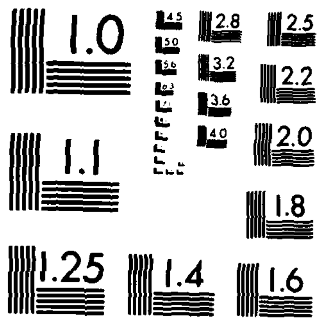

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SPECIAL STUDY

OCTOBER 1981

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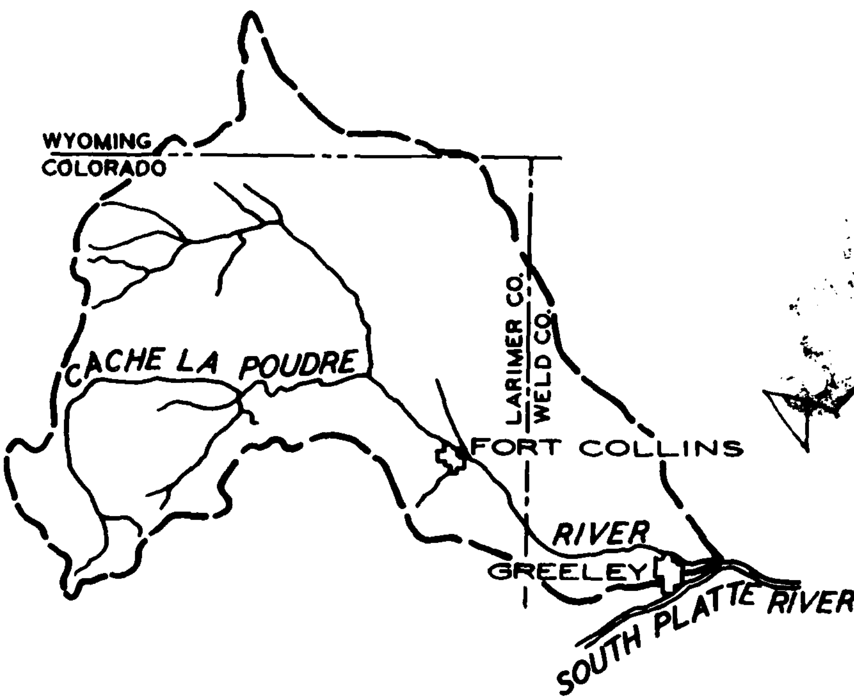
CACHE LA POUDRE RIVER BASIN
LARIMER - WELD COUNTIES, COLORADO

VOLUME II
HYDROLOGY



US Army Corps
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER N/A	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Cache la Poudre River basin, Larimer-Weld Counties Colorado		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) U. S. Army Corps of Engineers, Omaha District		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Corps of Engineers, Omaha District		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Department of the Army, Omaha District Corps of Engineers, 6014 U. S. Post Office and Courthouse, Omaha, NE 68102		12. REPORT DATE October 1981 13. NUMBER OF PAGES 4 v. :ill., maps, graphs
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

At head of title: Special study.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Floods,
Floodplains, - Colorado,
Flood damage prevention, Tables (Data), Maps ←

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Cache la Poudre River basin in Colorado is in a rapidly growing area. The population of Larimer and Weld Counties increased by about 60 percent between 1970 and 1980. The basin contains a number of flood hazard areas, from narrow canyon flood plains in the mountainous west to wide valley flood plains in the east. Local interests are concerned about the changine nature of the flood hazards in the basin as a consequence of urban growth, particularly since the catastrophis Big Thompson River flood in the summer of 1976. Originator-supplied keywords included.

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SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO

VOLUME I	FLOOD HAZARD, DAM SAFETY, AND FLOOD WARNING
VOLUME II	HYDROLOGY
VOLUME III	FLOOD PLAIN ANALYSIS, SHEEP DRAW
VOLUME IV	FLOOD PLAIN ANALYSIS, FOSSIL CREEK

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SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO

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October 1981

SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO

VOLUME II
HYDROLOGY

Introduction

BACKGROUND

The Cache la Poudre River basin in Colorado is in a rapidly growing area. The population of Larimer and Weld Counties increased by about 60 percent between 1970 and 1980. The basin contains a number of flood hazard areas, from narrow canyon flood plains in the mountainous west to wide valley flood plains in the east. Local interests are concerned about the changing nature of the flood hazards in the basin as a consequence of urban growth, particularly since the catastrophic Big Thompson River flood in the summer of 1976. Discussions regarding a wide ranging study of the basin were initiated between the Omaha District Corps of Engineers and local planners and elected officials in 1977 and a plan of study was agreed upon.

AUTHORITY

This study was made under continuing authority in Section 206 of the 1960 Flood Control Act, as amended.

PURPOSE

The purpose of this study was to analyze flood-related problems and provide information that will enable local governments to make decisions that will minimize or reduce flood hazards in the future.

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SCOPE OF THE SPECIAL STUDY

The course of the study was primarily determined through coordination with the Omaha District, Colorado Water Conservation Board, Larimer County, Weld County, the city of Fort Collins, the city of Greeley, and the Larimer-Weld Regional Council of Governments. Numerous other agencies and private interests were also contacted during the study.

As the study progressed, tasks were deleted or added in consultation with local interests to respond to changes in identified needs or priorities. Since some work items were independent of other study tasks, the study results are presented in four separate volumes. Volume I considers basin flood hazards, dam safety, and flood warning. Volume II presents the detailed hydrologic analysis for the basin. Volumes III and IV present flood plain studies for Sheep Draw and Fossil Creek, respectively which are two tributaries of the Cache la Poudre River located in the path of current urbanization. All geographic locations referred to are in the State of Colorado unless otherwise indicated.

PURPOSE AND SCOPE OF VOLUME II

The purpose of Volume II is to present the details of the hydrologic studies made in support of the Cache La Poudre River Basin Special Study. Data from these studies are used in the other volumes of this report.

Streams analyzed include the Cache la Poudre River, several tributaries in the mountains, and Fossil Creek and Sheep Draw in the plains. Discharges were computed for floods of various probabilities of occurrence. Hydrologic modeling studies are described including assumptions made. If appropriate, the effect of future urban growth on flood discharge was included for a particular watershed.

Cache La Poudre River Hydrology

GENERAL

This section outlines hydrologic studies for the Cache la Poudre River and several tributaries. Discharges are determined for the 10-, 50-, 100-, and 500-year floods for existing conditions. Future urbanization was considered to have no significant effect on the Cache la Poudre River.

Hydrologic studies for the Cache la Poudre River downstream from the North Fork Cache la Poudre River were completed in 1973. These studies were used in three Flood Plain Information Reports covering the Cache la Poudre River. Volume I concerned the Fort Collins area (published October 1973), Volume II covered the Greeley area (March

1974) and Volume III presented data for the reach between Fort Collins and Greeley (October 1975). The hydrologic studies that served as the basis for these reports are referred to herein as the 1973 studies.

BASIN DESCRIPTION

The Cache la Poudre River, a left-bank tributary to the South Platte River, has its source in the Rocky Mountains west of Fort Collins. From the Continental Divide, the Cache la Poudre River flows in a general northerly direction and then turns eastward flowing past Rustic and Poudre Park. Approximately 5 miles downstream from Poudre Park, the North Fork of the Cache la Poudre River joins the main stem of the Cache la Poudre River. The Cache la Poudre River drains an area of about 1,055 square miles at the U.S. Geological Survey (USGS) stream gaging station located at the bluffline approximately 4 miles downstream from this confluence. At the bluffline, the Cache la Poudre River leaves the mountains and flows in a southeasterly direction through the northern edge of Fort Collins and Greeley to its confluence with the South Platte River about 5 miles downstream from Greeley. Three miles upstream from the mouth of the Cache la Poudre River at the USGS stream gaging station, the river has a drainage area of about 1,877 square miles. Elevations in the basin range from 4,600 feet to over 13,500 feet above mean sea level.

EXISTING STRUCTURES

Worster, Halligan, and Seaman are reservoirs that were studied in detail to account for their attenuating effect on flood peak discharges. Worster Reservoir, also known as Eaton Reservoir, is located in the upper North Fork Cache la Poudre River basin on Sheep Creek. The reservoir is used for irrigation. Halligan Reservoir, built on the North Fork Cache la Poudre River about eight miles northwest of Livermore, is used for the storage of irrigation water. Seaman

Reservoir is located on the North Fork Cache la Poudre River just upstream from its confluence with the Cache la Poudre River and is used for municipal water supply storage. Other reservoirs exist in the mountains but their contributing areas are too small to be of any consequence with regard to floodflow alteration. Many reservoirs in the plains have small contributing areas and, lacking residual flood storage, have little effect on discharges on the Cache la Poudre River.

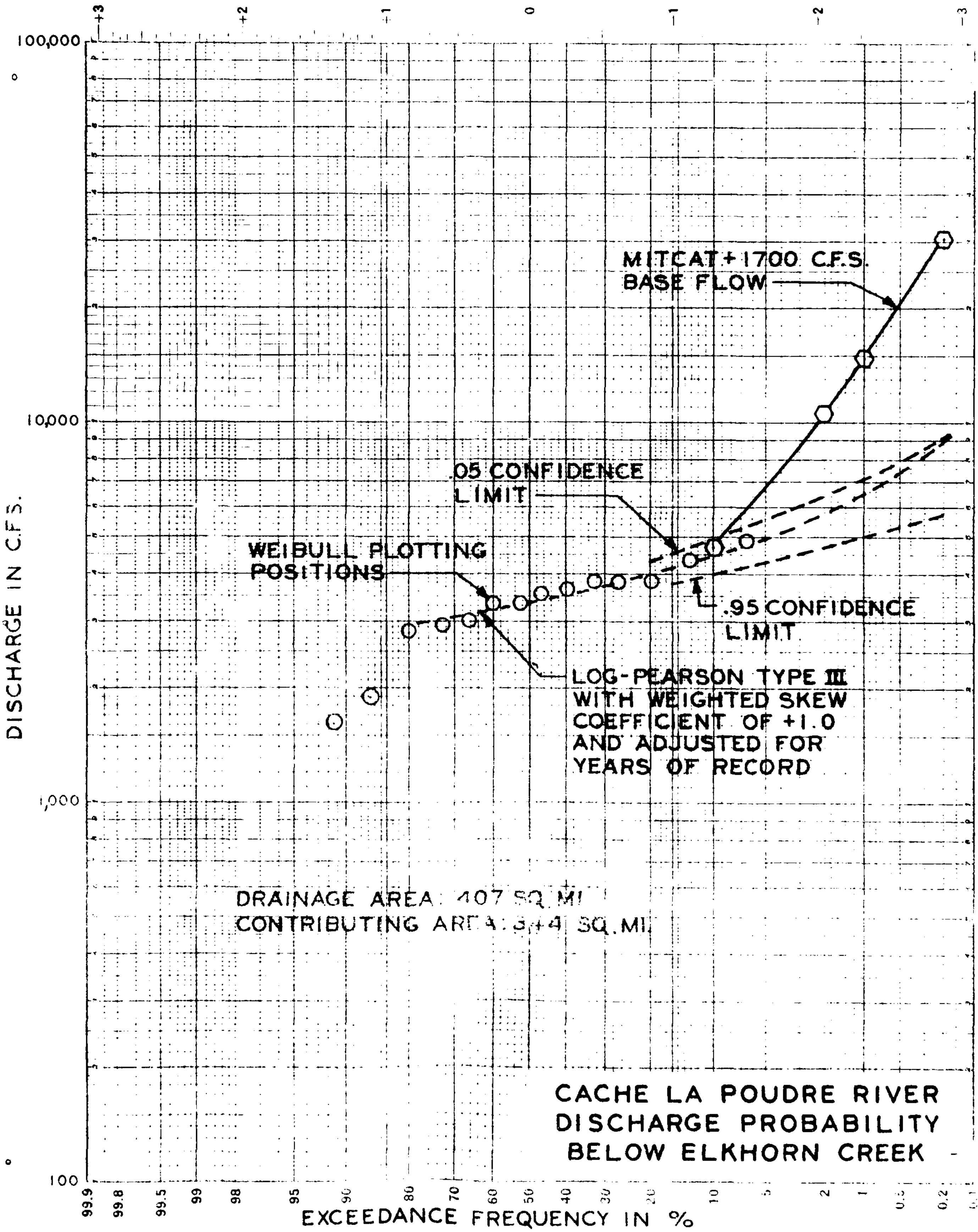
DISCHARGE PROBABILITY AT GAGE SITES

GENERAL

A preliminary discharge-probability analysis was made for the Cache la Poudre River at the USGS stream gaging stations located below Elkhorn Creek and at the mouth of the canyon. The analytical methods presented in Bulletin No. 17 published by the Water Resources Council (WRC) were used for these gages. The USGS stream gaging station located 3 miles upstream from the mouth of the Cache la Poudre River near Greeley was analyzed in the 1973 studies using Beard's statistical methods. The results of these studies are discussed in the following paragraphs. All flood discharges were adjusted for expected probability.

BELOW ELKHORN CREEK

This gage is approximately 10 miles upstream from Poudre Park. The gage is downstream from Elkhorn Creek which, in turn, is about 1 mile downstream from the South Fork Cache la Poudre River. Fourteen years of record from 1946 through 1959 are available for analysis. All of the annual peak discharges appear to be from snowmelt. A generalized skew coefficient of +1 obtained from a Corps of Engineers regional study of similar streams in Colorado was used to help shape the distribution. Frequency data for these streams are given in table 1. The resulting curve, with confidence limits and adjustments for length of record, is shown in figure 1.



CACHE LA POUDRE RIVER
DISCHARGE PROBABILITY
BELOW ELKHORN CREEK

FIGURE 1

Table 1
Frequency Data For
Mountain Streams in the South Platte River Basin

Stream	Drainage Area (sq. mi.)	Record Length	Computed Skew	Standard Deviation	Mean Flood (c.f.s.)	Record Floods: Discharge (c.f.s.)	Record Floods: Ratio To Mean	Record Floods: Standard Deviate
Bear Creek at Morrison	164	55	+1.03	0.446	522	8,600	16.5	2.73
Bear Creek at Morrison						8,100	15.5	2.67
Bear Creek at Morrison						6,200	11.9	2.19
Clear Creek Near Golden	399	57	+0.27	0.250	1,630	5,890	3.6	2.20
Clear Creek Near Golden						5,250	3.2	2.00
Clear Creek Near Golden						5,140	3.2	1.97
South Boulder Near Eldorado Springs	109	74	+1.19	0.245	605	7,390	12.2	4.44
South Boulder Near Eldorado Springs						2,370	3.9	2.42
South Boulder Near Eldorado Springs						1,440	2.4	1.54
Boulder At Orodell	102	58	+0.33	0.188	651	2,500	3.8	3.11
Boulder At Orodell						1,300	2.0	1.60
Boulder At Orodell						1,290	2.0	1.58
Boulder At Boulder	131	77	+1.66	0.226	985	11,000	11.2	4.63
Boulder At Boulder						5,000	5.1	3.12
Boulder At Boulder						3,000	3.0	2.14
St. Vrain At Lyons	212	71	+0.98	0.276	1,150	10,500	9.1	3.47
St. Vrain At Lyons						9,400	8.2	3.30
St. Vrain At Lyons						3,920	3.4	1.92
Cache La Poudre Near Fort Collins	1,055	81	+0.82	0.215	3,440	21,000	6.1	3.66
Cache La Poudre Near Fort Collins						12,000	3.5	2.53
Cache La Poudre Near Fort Collins						10,200	3.0	2.20

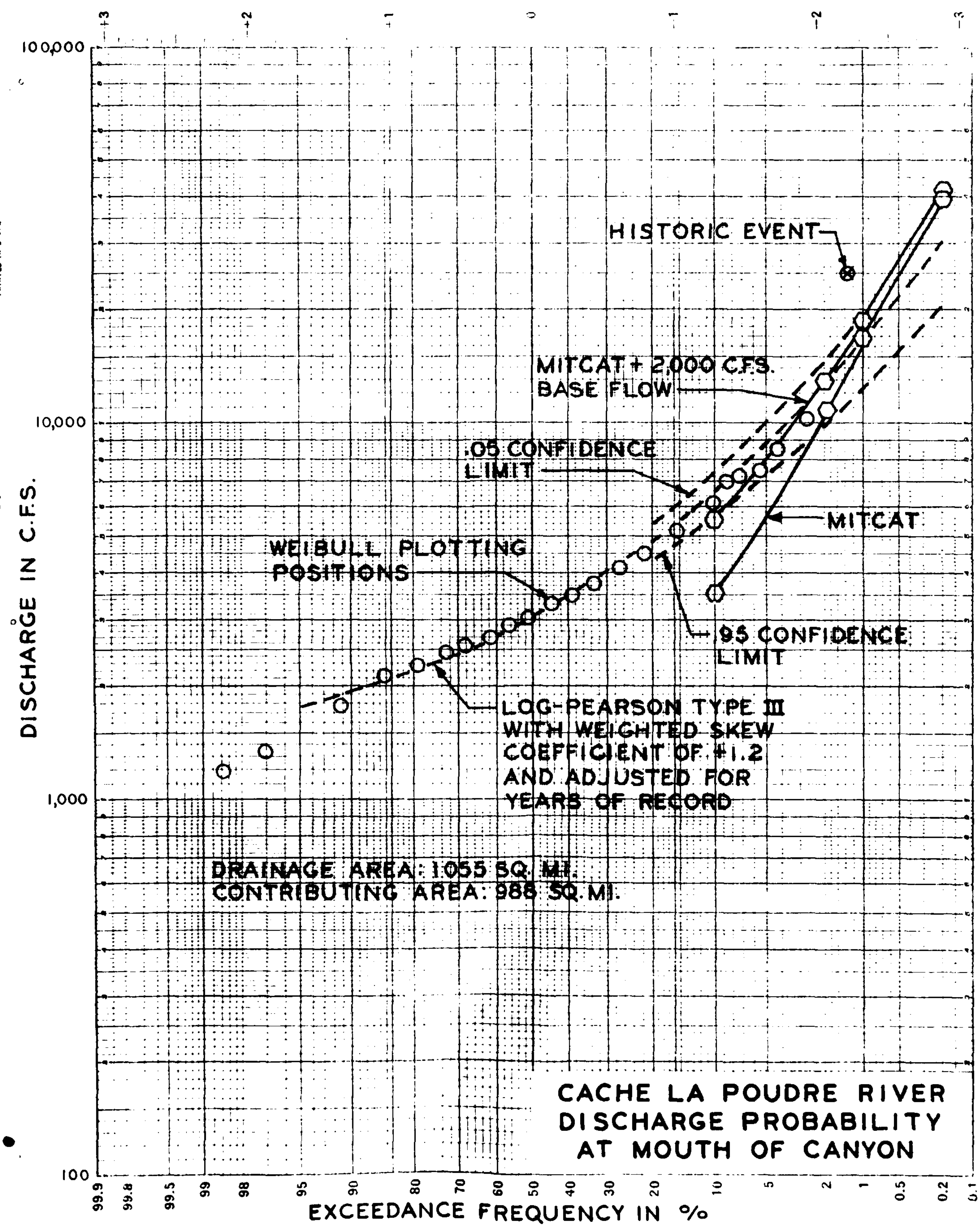
NOTE: The 1% deviate from a Pearson Type III +1 skewed distribution is 3.03.

MOUTH OF CANYON

This gage is located about 2 miles west of the junction of Colorado Highway 14 and U.S. Highway 287 northwest of Fort Collins. The period of discharge records available at this stream gage was from 1882 to 1976 including an estimated discharge for the 1904 event. In the final discharge-probability analysis of the gaged data, the period 1910 to 1976 was selected as being the most representative of existing control conditions in the basin. The years of record prior to 1910, except 1904, were not used because Halligan Reservoir, built on the North Fork in 1910, provides significant attenuation effects downstream. The gage was destroyed during the flood of 20 and 21 May 1904. Follansbee and Sawyer in Floods in Colorado, USGS, 1948, quote J. A. Armstrong, an irrigation engineer who investigated the flood, as saying that the storm was centered "about Stonewall Mountain at the head of Stonewall Creek . . . The volume of water passing Livermore has been estimated at 20,000 cubic feet per second." Since most of the runoff generated by the 1904 storm was below the Halligan Reservoir site, the flood with an estimated peak discharge of 25,000 cubic feet per second was used in the frequency analysis as a historic event. The flood routings of Seaman Reservoir indicated very little effect on downstream peak discharges. Therefore, no adjustments of the annual peaks were required for the period of record before Seaman Reservoir became operational in 1947. The generalized skew coefficient of +1 obtained from the Corps of Engineers regional study of similar streams was used to help shape the distribution. The computed skew of +1.3 was weighted with the +1 generalized skew coefficient, giving an adopted skew of +1.2. The resulting curve, along with confidence limits and adjustments for length of record, is shown in figure 2.

NEAR GREELEY

This gage was analyzed in the 1973 studies. The discharge-probability analysis of the Greeley stream gage was based on 51 years of record, from 1916 to 1970. The frequency curve was normally distributed



HISTORIC EVENT
MITCAT + 2,000 C.F.S. BASE FLOW
.05 CONFIDENCE LIMIT
MITCAT
WEIBULL PLOTTING POSITIONS
.95 CONFIDENCE LIMIT
LOG-PEARSON TYPE III WITH WEIGHTED SKEW COEFFICIENT OF +1.2 AND ADJUSTED FOR YEARS OF RECORD
DRAINAGE AREA: 1055 SQ. MI.
CONTRIBUTING AREA: 988 SQ. MI.
CACHE LA POUDRE RIVER
DISCHARGE PROBABILITY
AT MOUTH OF CANYON
DISCHARGE IN C.F.S.
EXCEEDANCE FREQUENCY IN %

FIGURE 2

and adjusted for partial duration series. The curve, shown in figure 3, gives a 100-year flood discharge of 10,700 cubic feet per second. A WRC update of the record from 1916 to 1977 with zero adopted skew and expected probability gives a 100-year flood discharge of 10,400 cubic feet per second. A variation of this update, in which an estimated 1904 event of 18,000 cubic feet per second is considered the highest event since 1864, gives 10,700 cubic feet per second for the 100-year flood discharge. The 1864 flood appears to have been about the same magnitude as the 1904 flood. In describing the 1904 flood, Floods in Colorado states "below the Union Pacific Railroad tracks in Greeley, the lowlands were overflowed, and the houses in that area were submerged to their window sills." A cross section of the Cache la Poudre River near this location indicates a channel and overbank capacity of about 10,000 cubic feet per second at an elevation that would reach the windowsills of houses in the area. Since the updated 100-year flood discharge remains near 10,700 cubic feet per second, the results of the 1973 study remain valid and are used in this report.

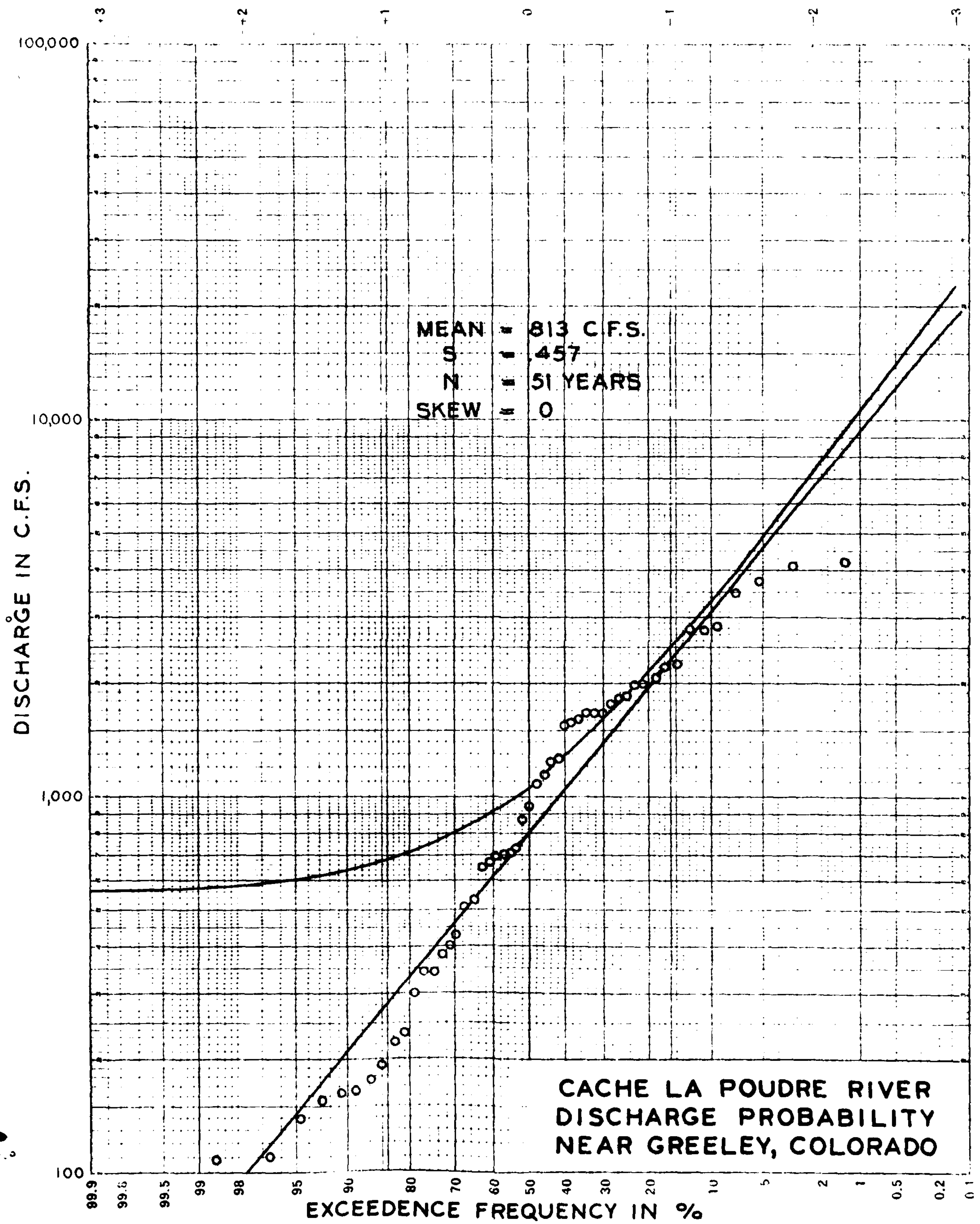
MODELING STUDIES

GENERAL

The Massachusetts Institute of Technology Catchment Model (MITCAT) computer program was used to model the Cache la Poudre River basin upstream from the USGS stream gage site at the mouth of the canyon. This is a computer model which estimates runoff based on rainfall and basin characteristics. The model was calibrated to the 1-percent discharge given by the WRC frequency analysis of the annual peaks. The plains portion of the Cache la Poudre River basin was analyzed using synthetic unit hydrographs. This discussion of modeling studies applies to the mountain area, which was analyzed by the MITCAT model.

RAINFALL

Rainfall values for the 10-, 50-, and 100-year, 6-hour events were obtained from the Precipitation-Frequency Atlas of the Western United



MEAN = 813 C.F.S.
S = .457
N = 51 YEARS
SKEW = 0
CACHE LA POUDRE RIVER
DISCHARGE PROBABILITY
NEAR GREELEY, COLORADO
DISCHARGE IN C.F.S.
EXCEEDENCE FREQUENCY IN %
100,000
10,000
1,000
100

FIGURE 3

States, Atlas 2, Volume III, Colorado, published by the National Oceanic and Atmospheric Administration (NOAA) in 1973. In each case, a 500-year value was estimated by extrapolating the selected Atlas values on semilogarithmic paper. Adjustments for depth-area were based on the depth-area relationship presented in the NOAA publication. Adjustments for length of record were made on logarithmic-probability paper using Beard's table of expected probability adjustments for various lengths of record. The spatial variation of the rainfall potential shown in the Atlas for the Cache la Poudre River basin was simulated in the MITCAT model through the introduction of several hyetographs. The time variation of the 6-hour rainfall for each hyetograph was based on a study of hourly precipitation data recorded during major storms in the South Platte River basin and refined to 30-minute values by using Civil Works Bulletin 52-8, Plate No. 11 (1952) as a guide. The 6-hour distribution is given in table 2 below.

Table 2
6-Hour Rainfall Distribution

End of Period (minutes)	Percent of 6-Hour
30	2
60	4
90	4
120	5
150	9
180	10
210	40
240	10
270	6
300	4
330	4
360	2

LOSSES

The Soil Conservation Service (SCS) curve number technique was used to model infiltration in the MITCAT model. A general soil map of Larimer

County published in 1976 by the Colorado State University (CSU) Experiment Station in cooperation with the SCS indicates that most of the soils in the mountainous portion of the Cache la Poudre River basin belong to Hydrologic Soil Group B. Technical Release No. 55 published by the SCS was used to select curve numbers based on soil group and land use. Selected curve numbers were 60 for forested areas and 66 for pasture and rangeland. Curve number 66 also describes wood or forest land with a thin stand, poor cover, and no mulch. A value of 1.0 inch for detention storage was chosen on a trial and error basis in order to calibrate the model.

CALIBRATION

The WRC frequency analysis of the gaged data at the mouth of the canyon was used to calibrate the MITCAT model. Due to a limitation of a total of 200 catchments and streams in MITCAT, separate models were developed for the North Fork Cache la Poudre River and the Cache la Poudre River upstream from the North Fork. Rainfall was applied to the modeled 988 square miles of the contributing area upstream from the gage. SCS curve numbers were selected as described in the preceding paragraph and were held constant. Overland flow lengths were chosen as either 1,200 feet or 1,600 feet, depending upon the topography of each catchment. Detention storage was the only parameter that was varied. By a trial and error analysis, a value of 1.0 inch for detention storage produced a modeled discharge of 16,600 cubic feet per second at the gage for the 100-year flood event. The calibration studies indicated that the MITCAT model was sensitive to detention storage. After adjusting for an average annual June base flow of 2,000 cubic feet per second, the resulting 100-year flood model discharge was 18,600 cubic feet per second. The same procedure was used to determine the 10-, 50-, and 500-year flood events. The discharge-frequency curve derived from this analysis is shown in figure 2. It crosses the WRC-developed curve at about the 30-year level. The departure from the WRC curve at this point appears reasonable since the record is biased by a mix of

flood-producing populations. The more frequent snowmelt events tend to be more predictable and less severe, while the rainfall-generated floods are extremely variable and can reach spectacular proportions.

DISCHARGE-PROBABILITY RELATIONSHIPS

GENERAL

Discharge-probability profiles for the Cache la Poudre River upstream from the North Fork Cache la Poudre River, the North Fork Cache la Poudre River from Halligan Reservoir to its confluence with the Cache la Poudre River, and for Lone Pine Creek were developed from MITCAT models of the mountainous portion of the basin. The discharge profile for the plains was obtained from the 1973 hydrologic study.

CACHE LA POUDRE RIVER UPSTREAM FROM THE NORTH FORK CACHE LA POUDRE RIVER

Discharges for the 422 square miles of contributing area of the Cache la Poudre River basin upstream from the North Fork Cache la Poudre River were obtained by inserting the 10-, 50-, 100-, and 500-year rainfall values into the calibrated MITCAT model. An average June base flow of 1,700 cubic feet per second was added to the modeled discharges. Discharges for the Cache la Poudre River from Poudre Park to its confluence with the North Fork Cache la Poudre River are given in table 3. The gulches referred to are shown In figure 4.

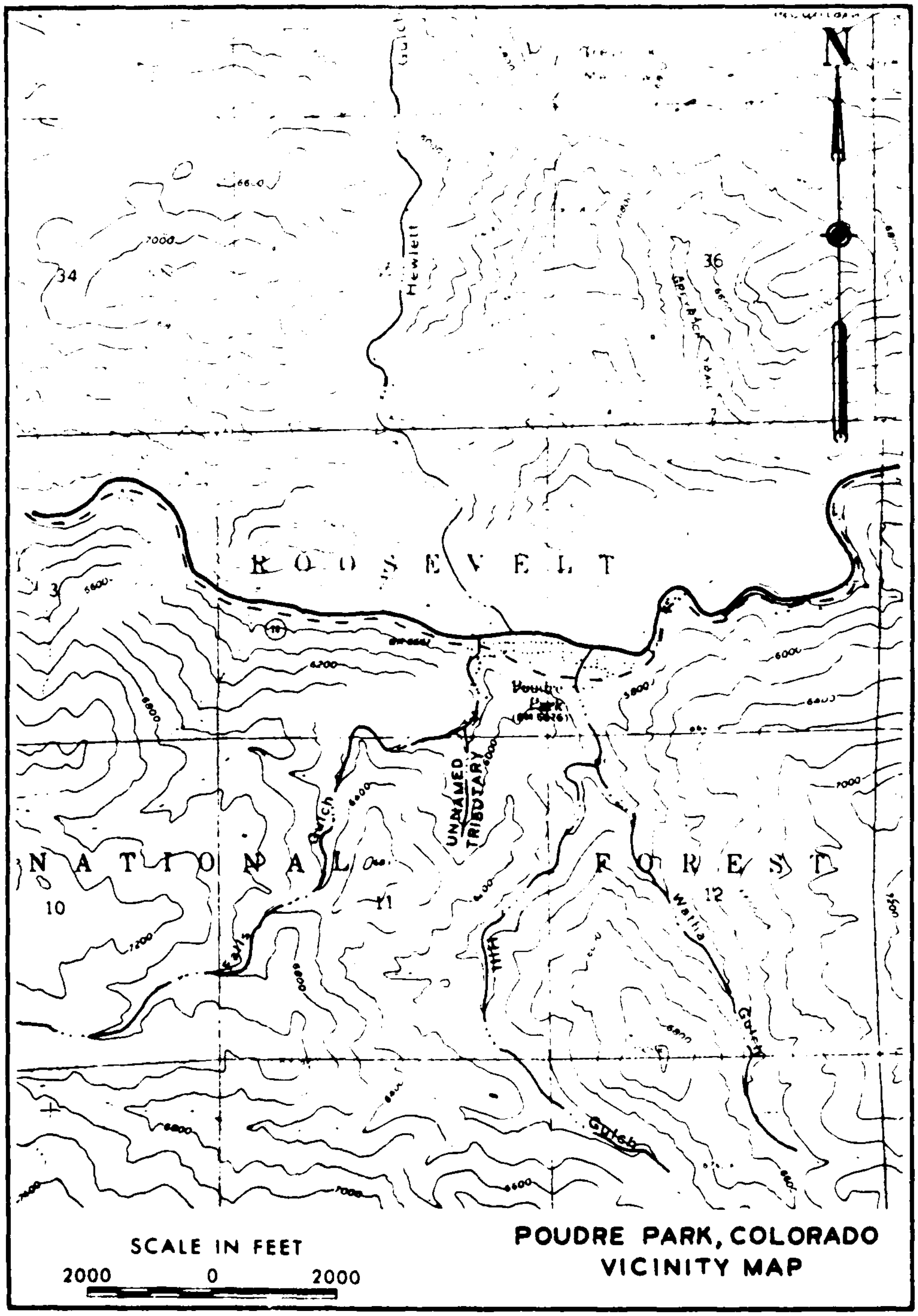


FIGURE 4

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Table 3
Cache La Poudre River
Mountain Area
Discharge-Probability Relationships

Station	Contributing Drainage Area (sq. mi.)	Flood 10-Yr (c.f.s.)	Flood 50-Yr (c.f.s.)	Flood 100-Yr (c.f.s.)	Flood 500-Yr (c.f.s.)
U/S[1/] from Hewlett Gulch & Falls Gulch	385	4,960	11,590	16,300	31,870
D/S[2/] from Hewlett Gulch & Falls Gulch	409	5,170	12,280	17,320	36,220
U/S from Hill Gulch	409	5,170	12,280	17,320	36,220
D/S from Hill Gulch	415	5,220	12,460	17,580	36,820
U/S from Confluence with North Fork	422	5,230	12,520	17,700	37,040

1/ U/S - Upstream
2/ D/S - Downstream

NORTH FORK CACHE LA POUDRE RIVER

Two storms were used to generate the North Fork Cache la Poudre River discharges given in table 4. A storm over the 354-square-mile drainage area upstream from Halligan Reservoir produced the greatest discharges from Halligan Reservoir to upstream from Stonewall Creek. Stonewall Creek enters the North Fork Cache la Poudre River from the left about one-half mile upstream from Lone Pine Creek. Rabbit Creek, also listed in table 4, enters the main river from the right about 1 mile upstream from Lone Pine Creek. Downstream from Stonewall Creek to the mouth of the North Fork Cache la Poudre River, a storm over the entire 566-square-mile area of the North Fork Cache la Poudre River was the most critical. A 300-c.f.s. base flow was added to the North Fork Cache la Poudre River discharges.

Table 4
North Fork Cache La Poudre River
Discharge-Probability Relationships

Station	Drainage Area (sq. mi.)	Flood 10-Year (c.f.s.)	50-Year (c.f.s.)	100-Year (c.f.s.)	500-Year (c.f.s.)
U/S from Halligan Reservoir	354	3,440	10,480	14,980	32,120
D/S from Halligan Reservoir	354	1,980	6,290	9,260	22,790
Rabbit Creek	412	1,970	6,250	9,220	22,490
U/S from Stonewall Creek	412	1,970	6,240	9,190	22,440
D/S from Stonewall Creek	444	2,020	6,440	9,800	23,000
U/S from Lone Pine Creek	445	2,020	6,430	9,800	22,950
D/S from Lone Pine Creek	532	2,510	8,000	12,170	27,970
U/S from Seaman Reservoir	565	2,570	8,080	12,280	27,890
D/S from Seaman Reservoir	565	2,490	7,790	11,830	26,960
Mouth	566	2,490	7,780	11,830	26,940

LONE PINE CREEK

Lone Pine Creek is an 87-square-mile, right-bank tributary of the North Fork Cache la Poudre River. Discharges from the confluence of the North and South Forks of Lone Pine Creek to the mouth of Lone Pine Creek are given in table 5.

Table 5
Lone Pine Creek
Discharge-Probability Relationships

Station	Drainage Area (sq. mi.)	Flood 10-Year (c.f.s.)	50-Year (c.f.s.)	100-Year (c.f.s.)	500-Year (c.f.s.)
U/S from South Lone Pine Creek	38	550	1,500	2,120	4,180
D/S from South Lone Pine Creek	65	920	2,570	3,660	7,230
U/S from Right-Bank Tributary	74	1,040	2,860	4,080	8,080
D/S from Right-Bank Tributary	78	1,130	3,070	4,380	8,620
Mouth	87	1,260	3,380	4,810	9,510

TRIBUTARIES AT POUDRE PARK

Results of the hydrologic portion of a special study at Poudre Park, Colorado, are presented in this report. Discharges for the 10-, 50-, 100-, and 500-year floods are given in table 6 for tributaries of the Cache la Poudre River at Poudre Park. Data for the Cache la Poudre River have been presented in preceding sections of this report. Hill Gulch and Falls Gulch are right-bank tributaries draining a total of about 7 square miles. Hewlett Gulch is a left-bank tributary with a drainage area of about 23 square miles. Figure 4 is a map of the Poudre Park vicinity.

Peak discharges generated from the Cache la Poudre River tributaries at Poudre Park were assumed to be noncoincident with the Cache la Poudre River flood discharges. In order to maintain continuity with the Cache la Poudre River rainfall values, 6-hour storms were applied to the watersheds of Hill Gulch, Falls Gulch, and Hewlett Gulch. Small areas are generally the most sensitive to short duration storms, but storm duration is not reflected in the SCS curve number method. The SCS National Engineering Handbook, Notice 4-102, August 1972, page

10.3, states that the rainfall-runoff relation of the SCS curve number method "excludes time as an explicit variable; this means that rainfall intensity is ignored. If everything but storm duration or intensity is the same for two storms, the estimate of runoff is the same for both storms." For this reason, the discharges presented in table 6 for the Cache la Poudre River tributaries at Poudre Park are generated as stated above from 6-hour storms.

Table 6
Cache la Poudre River Tributaries
Poudre Park, Colorado
Discharge-Probability Relationships

Station	Drainage Area (sq. mi.)	Flood 10-Year (c.f.s.)	50-Year (c.f.s.)	100-Year (c.f.s.)	500-Year (c.f.s.)
Hewlett Gulch at the Mouth	23.20	600	1,790	2,700	6,090
Falls Gulch at the Mouth	1.34	90	260	380	730
Unnamed Trib 1,500 ft. U/S from Mouth of Falls Gulch	0.14	10	30	40	90
Falls Gulch U/S from Confluence with Unnamed Trib	1.15	70	220	320	630
Hill Gulch at the Mouth	5.57	360	1,080	1,520	2,970
Watha Gulch at the Mouth	1.09	80	230	330	660
Hill Gulch U/S from the Confluence with Watha Gulch	4.35	280	850	1,220	2,330

SIMULATION OF FOREST FIRES

A 50-square-mile area in the Idylwilde-Kinikinik area, about midway between Spencer Heights and Rustic, was used to demonstrate the adverse effects on runoff that could be caused by a forest fire. Figure 9.6 in the SCS National Engineering Handbook, Section 4, Hydrology, August 1972, indicates that a curve number of 60 for soil group B is representative of a 45-percent ground cover density for a juniper-grass complex. Reducing the ground cover to 25 percent raises the curve number to 70. Ten-percent cover, the lowest that might be expected in a burned forest, corresponds to a curve number of 77. Curve numbers 70 and 77 were used in the 50-square-mile area while the other 365 square miles of the basin remained at curve number 60. The higher discharges caused by raising the curve numbers are shown as profiles in figure 5. Since the plains area was not modeled, the effects of a forest fire on discharge downstream from the North Fork Cache la Poudre River are not shown.

CACHE LA POUDRE RIVER DOWNSTREAM FROM THE NORTH FORK CACHE LA POUDRE RIVER

Synthetic unit hydrographs were developed for major subareas of the plains portion of the basin. These unit hydrographs were based on regional relationships that were determined from unit graph studies of other mountain and high plains tributaries in the South Platte River basin. Snyder's unit hydrograph constants, derived from the regional relationships, were used to develop unit hydrographs for the subareas. The 1-percent flood or 100-year flood hydrographs were developed by using 100-year, 1-hour rainfall values taken from U.S. Weather Bureau Technical Publication No. 40. The selected rainfall values were reduced for size of area and for a loss rate of 0.60 inch per hour. The resulting runoff value was applied to the respective unit hydrograph peak and adjusted for expected probability. The 100-year flood hydrographs were combined and routed along the Cache la Poudre River by the modified Puls S+Q/2 method. At selected locations, the routed

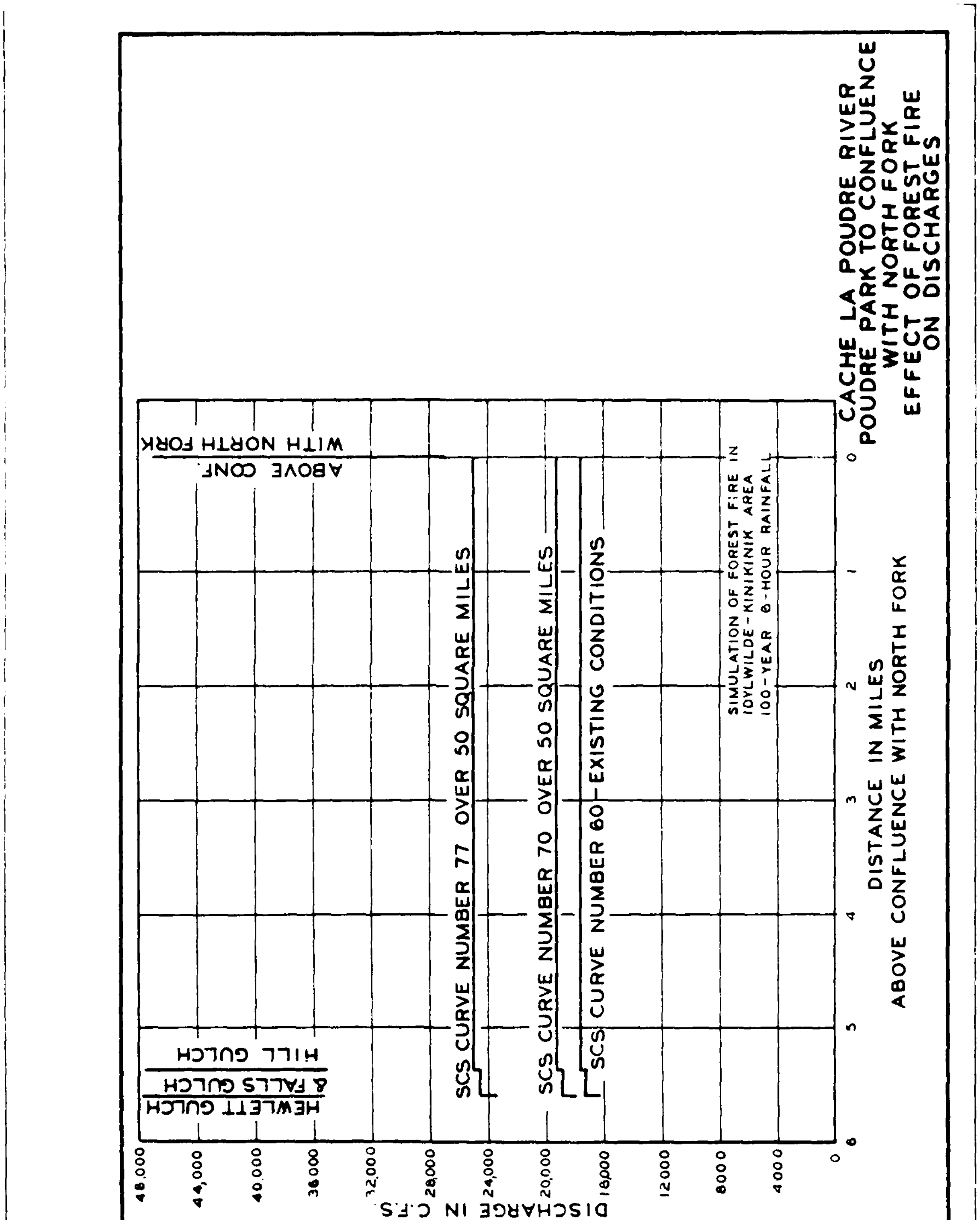

FIGURE 5

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100-year flood discharges were plotted on logarithmic-normal paper and a discharge-probability curve was drawn by using a standard deviation that was prorated from the computed standard deviations of 0.232 at the Fort Collins stream gage and 0.457 at the Greeley stream gage. The proration was linear, based on channel distance from the respective gaging stations. The resulting discharge-probability curves were used to determine the 10-, 50-, and 500-year discharges at each location. Discharges for the Cache la Poudre River from the bluffline to the mouth are given in table 7. Coalbank Creek is a poorly defined watercourse entering the Cache la Poudre River from the north about 3 miles upstream from Eaton Draw.

Table 7
Cache La Poudre River
Plains Area
Discharge-Probability Relationships

Station	Drainage Area (sq. mi.)	Flood 10-Year (c.f.s.)	50-Year (c.f.s.)	100-year (c.f.s.)	500-year (c.f.s.)
Bluffline	1,055	7,000	13,500	17,400	31,000
U/S from Dry Creek	1,102	8,400	13,700	16,200	23,800
D/S from Dry Creek	1,195	10,100	16,600	19,700	28,200
U/S from Boxelder Creek	1,245	8,000	13,700	16,600	24,000
D/S from Boxelder Creek	1,537	17,700	23,700	28,500	42,000
U/S from Consolidated Law Ditch	1,662	2,650	5,200	6,600	10,700
D/S from Consolidated Law Ditch	1,707	4,400	8,700	11,000	17,900
U/S from Coalbank Creek	1,747	2,250	4,800	6,300	10,900
D/S from Coalbank Creek	1,810	3,400	7,300	9,600	16,500
U/S from Eaton Draw	1,825	2,680	6,000	8,100	14,600
D/S from Eaton Draw	1,875	3,550	8,000	10,700	19,000
Mouth	1,890	3,100	7,100	9,400	16,800

Fossil Creek Hydrology

GENERAL

This section describes the hydrologic studies for Fossil Creek, a tributary of the Cache la Poudre River located south of Fort Collins, Colorado. Discharges for the 10-, 50-, 100-, and 500-year floods were developed for existing and projected urbanized conditions.

BASIN DESCRIPTION

Fossil Creek, a right-bank tributary to the Cache la Poudre River, has its source downstream from the southern end of Horsetooth Reservoir. A map of the Fossil Creek basin is shown on plate 2. Flowing in a general easterly direction from its source, Fossil Creek crosses U.S. Highway 287 approximately 3 miles south of Fort Collins. From U.S. Highway 287, Fossil Creek flows in a southeasterly direction to Fossil Creek Reservoir, then east to its confluence with the Cache la Poudre River. Fossil Creek has a total drainage area of about 32 square miles and a contributing drainage area of about 29 square miles. Elevations in the basin range from 4790 feet to 5930 feet above mean sea level.

EXISTING STRUCTURES

There are six major structures in the Fossil Creek basin. The largest, Fossil Creek Reservoir, is used for irrigation. Although the reservoir does not have a specific flood control function, it provides some residual flood control effects downstream. Runoff generated from the relatively small drainage areas upstream from Nelson Reservoir, Mud Lake, Duck Lake, Robert Benson Lake, and Portner Reservoir was assumed

to be noncontributing to the peak discharge generated from the areas below each reservoir. A Trilby Lateral crossing in the northwest corner of the basin effectively dams a tributary, thereby causing it to be noncontributing. All pertinent highway, county road, and railroad structures were evaluated for their temporary flood control potential. Reservoir routings utilizing storage-discharge curves were made for 24 of these structures.

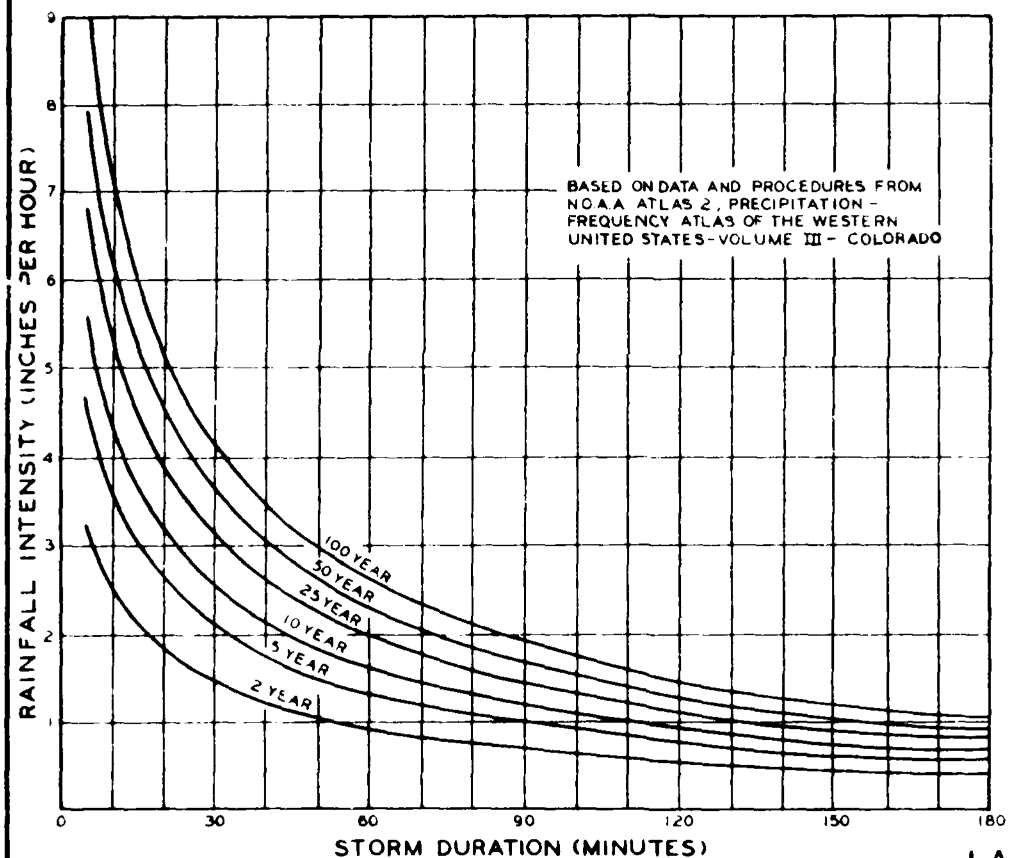
MODELING STUDIES

GENERAL

The Environmental Protection Agency's Storm Water Management Model (SWMM) computer program was used to model rainfall-runoff characteristics o' the Fossil Creek basin. Storms varying in frequency from 10 to 500 years were centered over the basin and modeled by SWMM to obtain the discharges presented in this report. The SWMM model of the Fossil Creek basin contains 161 catchments, 106 streams, reservoir routings for 24 road and railroad structures, and a routing for Fossil Creek Reservoir. Basin characteristics for the model were taken from USGS 7.5-minute quadrangle mapping having a scale of 1:24,000 and a contour interval of 10 feet. This SWMM model assumed dams in place, road crossings in place, and culverts open.

RAINFALL

Rainfall values for the 10-, 50-, and 100-year, 1-hour events were obtained from rainfall intensity-duration curves that were developed by Resource Consultants, Inc. of Fort Collins, Colorado. These curves were derived from data and procedures in Precipitation-Frequency Atlas of the Western United States, Atlas 2, Volume III, Colorado, published by NOAA in 1973. The rainfall intensity-duration curves are shown on figure 6. Resource Consultants, Inc. provided a 2-year, 1-hour rainfall that was obtained from a frequency analysis of 30 years of precipitation records at Fort Collins. This rainfall is 0.13 inch



LARIMER COUNTY
RAINFALL INTENSITY-DURATION CURVE
AREA I-FORT COLLINS AREA

FIGURE 6

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higher than the value that is given by the 2-year rainfall intensity-duration curve. The higher 2-year rainfall was recommended by Resource Consultants, Inc. for the Fossil Creek basin. The 500-year rainfall value was estimated by extrapolating the selected 1-hour values on semilogarithmic paper. Adjustments for depth-area were based on the depth-area relationship presented in the NOAA publication. At the request of local interests, it was decided that no expected probability adjustment would be applied to the rainfall in order to maintain uniformity with consultants who will be using the rainfall curves. The 1-hour distribution was obtained from a 2-hour storm that was provided by Resource Consultants, Inc. These data are shown in table 8. The Colorado Urban Hydrograph Procedure was used as a guide in rearranging the incremental rainfall values. This rearrangement generally gives the greatest incremental rainfall at the end of the first one-half hour of the storm. The 1-hour distribution is given in table 9.

Table 8
Fort Collins Design Storms
Total Precipitation
(in.)

2 hr - 5 min Storms

Time	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Percent
5	0.27	0.39	0.47	0.57	0.66	0.75	26
10	0.42	0.60	0.73	0.88	1.03	1.17	15
15	0.53	0.77	0.92	1.12	1.30	1.48	11
20	0.61	0.90	1.10	1.31	1.50	1.73	9
25	0.68	0.99	1.20	1.44	1.67	1.91	6
30	0.73	1.06	1.28	1.55	1.81	2.05	5
35	0.77	1.12	1.35	1.64	1.93	2.18	4
40	0.80	1.17	1.41	1.72	2.02	2.30	4
45	0.84	1.22	1.47	1.79	2.10	2.40	3
50	0.87	1.26	1.52	1.85	2.17	2.48	3
55	0.90	1.30	1.57	1.91	2.23	2.55	2
60	0.93	1.34	1.62	1.97	2.29	2.60	2
65	0.96	1.37	1.66	2.01	2.34	2.65	2
70	0.98	1.40	1.70	2.05	2.38	2.69	1
75	1.00	1.43	1.73	2.08	2.41	2.72	1
80	1.02	1.45	1.75	2.11	2.44	2.75	1
85	1.03	1.47	1.77	2.14	2.46	2.77	1
90	1.04	1.49	1.78	2.17	2.48	2.79	1
95	1.05	1.50	1.79	2.19	2.50	2.81	1
100	1.06	1.51	1.80	2.21	2.52	2.83	1
105	1.07	1.52	1.81	2.22	2.54	2.85	1
110	1.08	1.53	1.82	2.23	2.56	2.87	1
115	1.09	1.54	1.83	2.24	2.56	2.88	0
120	1.10	1.55	1.84	2.25	2.57	2.89	0

3 hr - 10 min Storms

10	0.42	0.60	0.73	0.88	1.03	1.17	38
20	0.61	0.90	1.10	1.31	1.50	1.73	18
30	0.73	1.06	1.28	1.55	1.81	2.05	10
40	0.80	1.17	1.41	1.72	2.02	2.30	8
50	0.87	1.26	1.52	1.85	2.17	2.48	6
60	0.93	1.34	1.62	1.97	2.29	2.60	4
70	0.98	1.40	1.70	2.05	2.38	2.69	3
80	1.02	1.45	1.75	2.11	2.45	2.75	2
90	1.05	1.49	1.79	2.17	2.50	2.79	1
100	1.07	1.52	1.82	2.21	2.54	2.83	1
110	1.09	1.55	1.85	2.25	2.57	2.87	1
120	1.11	1.58	1.88	2.29	2.60	2.91	1
130	1.13	1.61	1.91	2.33	2.63	2.95	1
140	1.15	1.63	1.93	2.36	2.66	2.99	1
150	1.17	1.65	1.95	2.39	2.69	3.02	1
160	1.19	1.67	1.97	2.42	2.72	3.05	1
170	1.21	1.69	1.99	2.44	2.75	3.08	1
180	1.23	1.71	2.01	2.46	2.77	3.11	1

SOURCE: Resource Consultants, Inc.

Table 9
1-Hour Rainfall Distribution

End of Period (minutes)	Percent of 1-Hour
5	4
10	4
15	5
20	6
25	9
30	26
35	15
40	11
45	6
50	5
55	5
60	4

LOSSES

Infiltration rates for the Fossil Creek basin were obtained from Soil Resources of Colorado, Region 2 - Larimer and Weld Counties, published in 1976 by the CSU Experiment Station in Fort Collins and the SCS. A general soil map of Larimer County used in conjunction with table 3 of the CSU publication lists ranges of infiltration permeabilities for each soil series. Table 10 contains the soil associations that were taken from the general soil map, the range of infiltration permeabilities for each soil series, and the infiltration rate that was used in the SWMM model.

Table 10
Infiltration Rates For Fossil Creek Basin

Soil Association	Soil Series	Permeability (inches/hour)	SWMM Infiltration Rate (inches/hour)
Otero-Nelson-Tassel			3.0
	Otero	6.0 - 20.0	
	Nelson	2.0 - 6.0	
	Tassel	2.0 - 6.0	
Haplustolls-Baller-Rock Outcrop			3.0
	Baller	2.0 - 6.0	
Nunn-Fort Collins-Ulm			
	Nunn	0.2 - 2.0	1.0
	Fort Collins	0.6 - 2.0	
	Ulm	0.2 - 0.6	
Laporte-Kim-Minnequa			1.0
	Laporte	0.6 - 2.0	
	Kim	0.6 - 2.0	
	Minnequa	0.6 - 2.0	
Heldt-Renohill-Kim			0.4
	Heldt	0.2 - 0.6	
	Renohill	0.2 - 0.6	
	Kim	0.6 - 2.0	

The infiltration rate of 0.4 inch per hour was used over most of the basin. Selected detention storage values are 0.3 inch for pervious areas and 0.2 inch for impervious areas.

LAND USE

The Fossil Creek basin is subject to increasing urban development from the city of Fort Collins. Changes in imperviousness that would result from land use changes will affect the runoff potential. To reflect the influence of changing development, three levels of urbanization were considered. Two of these urbanization levels, existing and projected, are shown in the report Larimer-Weld Region Land Use Alternatives prepared for the Larimer-Weld Regional Council of Governments in November 1977. The existing urbanization condition reflects little

significant development. Projected urbanization represents year 2000 urbanization and is an intermediate level of development in that the upstream half of the Fossil Creek basin is partially urbanized. Total urbanization assumes the basin is urbanized except for the rugged area west of Taft Hill Road.

Existing and future urbanization are shown on plate 3. The land use patterns were slightly altered to fit hydrologic subareas in the SWMM model.

Any changes in these land use projections and future urbanization boundaries would change the hydrologic and hydraulic data presented in this study.

The percent of imperviousness for each subcatchment was estimated for exist ng and projected urbanized conditions. Table 11 lists the percent of imperviousness for each land use that was considered in the model.

Table 11
Percent Imperviousness for Land Uses in the Fossil Creek Basin

Land Use	Impervious Area (percent)
Commercial	90
High Density Residential	52
Medium Density Residential	40
Low Density Residential	30
Agricultural	5

DISCHARGE-PROBABILITY RELATIONSHIPS

FOSSIL CREEK

The 10-, 50-, 100-, and 500-year flood discharges for existing and projected urban conditions for Fossil Creek are presented in table 12. To show the maximum effect of urbanization, the 100-year flood was computed with total urbanization.

Table 12
Fossil Creek
Discharge-Probability Relationships

Station		Drainage Area (sq. mi.)	Distance from Mouth (feet)	10-Year Flood Urbanization Exist. (c.f.s.)	10-Year Flood Urbanization Proj. (c.f.s.)	50-Year Flood Urbanization Exist. (c.f.s.)	50-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Exist. (c.f.s.)	100-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Tot. (c.f.s.)	500-Year Flood Urbanization Exist. (c.f.s.)	500-Year Flood Urbanization Proj. (c.f.s.)
Taft Hill Road	U/S	0.7	66,610	120	120	260	260	350	350	540	610	610
	D/S			90	90	160	160	180	180	210	220	220
Shields Street	U/S	1.2	59,675	220	360	470	650	590	800	850	850	1,130
	D/S			180	200	380	570	540	740	790	830	1,090
Stream C	U/S	1.3	58,910	180	220	400	620	570	800	850	890	1,180
	D/S	3.0		390	500	720	990	930	1,200	1,260	1,310	1,640
Stream A	U/S	3.2	55,300	400	520	700	960	910	1,180	1,280	[illegible]	1,610
	D/S	9.8		740	1,150	1,330	1,970	1,640	2,330	2,390	2,260	2,940
Colo. & Southern RR	U/S	9.9	53,875	770	1,170	1,340	2,000	1,660	2,380	2,430	2,310	3,030
	D/S			770	1,170	1,340	1,940	1,660	2,300	2,350	2,260	2,850
U.S. Highway 287	U/S	10.0	51,435	770	1,160	1,330	1,930	1,650	2,290	2,340	2,270	2,850
	D/S			770	1,160	1,330	1,930	1,650	2,280	2,330	2,260	2,820
Mail Creek	U/S	11.0	40,620	830	1,290	1,470	2,160	1,850	2,590	2,630	2,610	3,320
	D/S	12.3		930	1,590	1,730	2,670	2,240	3,140	3,230	3,190	4,130
County Road	U/S	12.4	38,775	930	1,590	1,740	2,680	2,250	3,200	3,240	3,200	4,150
	D/S			930	1,580	1,730	2,660	2,240	3,190	3,230	3,200	4,150
Right-Bank Trib.	U/S	14.2*	29,900	940	1,650	1,880	2,920	2,450	3,550	3,590	3,610	4,880
	D/S	16.7*		1,120	2,050	2,400	3,860	3,190	5,080	5,200	4,920	7,600
Union Pacific RR	U/S	16.7*	29,620	1,120	2,050	2,400	3,860	3,190	5,080	5,200	4,920	7,600
	D/S			590	970	1,230	1,360	1,340	1,420	1,430	1,460	1,510
County Road	U/S	17.9*	24,885	600	980	1,260	1,430	1,400	1,510	1,480	1,560	1,720
	D/S			470	770	1,070	1,300	1,300	1,390	1,400	1,450	1,510
Right-Bank Trib.	U/S	18.2*	12,990	470	760	1,070	1,300	1,300	1,390	1,400	1,460	1,510
	D/S	26.6*		650	810	1,590	1,600	2,120	2,130	3,680	3,360	3,360
Fossil Creek Dam	U/S	26.6*	12,620	650	810	1,590	1,600	2,120	2,130	3,680	3,360	3,360
	D/S			290	380	610	720	780	870	980	1,160	1,250
Mouth		29.1*	0	290	380	610	710	780	870	980	1,160	1,240

*Contributing Area

STREAM A

This stream originates in the southwest corner of the Fossil Creek basin and runs northeastward to join Fossil Creek at the Colorado and Southern Railroad as shown on plate 2. The 10-, 50-, 100-, and 500-year flood discharges for existing and projected urban conditions for this major Fossil Creek tributary are displayed in table 13. The 100-year flood was also computed for total urbanization.

STREAMS C AND B

These tributaries are shown on plate 2. The 10-, 50-, 100-, and 500-year flood discharges for existing and projected urban conditions on these tributaries are shown in table 14. Also shown are the 100-year discharges for total urbanization conditions.

Table 13
Stream A
Discharge-Probability Relationships

Station		Drainage Area (sq. mi.)	Distance from Trib. Mouth (feet)	10-Year Flood Urbanization Exist. (c.f.s.)	10-Year Flood Urbanization Proj. (c.f.s.)	50-Year Flood Urbanization Exist. (c.f.s.)	50-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Exist. (c.f.s.)	100-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Fut. (c.f.s.)	500-Year Flood Urbanization Exist. (c.f.s.)	500-Year Flood Urbanization Proj. (c.f.s.)
Taft Hill Road	U/S	1.2	21,220	130	130	480	480	720	720	1,020	1,280	1,280
	D/S			40	40	70	70	70	70	80	[illegible]	[illegible]
Right-Bank Trib.	U/S	2.3	14,650	160	160	380	380	500	490	[illegible]	740	740
	D/S	3.1		280	280	650	650	870	860	1,270	1,320	1,320
Shields Street	U/S	3.1	13,850	320	320	770	770	1,010	1,010	1,500	1,550	1,550
	D/S			190	190	270	270	450	450	720	970	970
Colo. & Southern RR	U/S	3.5	13,010	190	250	270	360	460	470	750	1,000	1,010
	D/S			190	220	240	260	440	460	740	960	970
Colo. & Southern RR		3.6	10,035	210	300	330	450	430	520	720	890	920
County Road	U/S	3.6	9,610	210	300	330	450	430	520	720	890	920
	D/S			210	260	280	360	410	450	700	840	880
Stream B	U/S	3.7	7,850	210	270	300	380	420	470	700	650	880
	D/S	6.1		410	480	570	660	730	780	1,140	1,400	1,490
Colo. & Southern RR	U/S	6.6	4,370	430	620	660	1,000	790	1,210	1,220	1,470	1,690
	D/S			430	610	660	970	790	1,130	1,150	1,340	1,460
Colo. & Southern RR	U/S	6.7	1,045	430	610	660	980	780	1,150	1,160	1,340	1,450
	D/S			430	610	660	970	780	1,140	1,150	1,330	1,440
Mouth		6.7	0	430	610	660	970	780	1,140	1,150	1,330	1,440

Table 14
Streams C and B
Discharge-Probability Relationships

Station		Drainage Area (sq. mi.)	Distance from Trib. Mouth (feet)	10-Year Flood Urbanization Exist. (c.f.s.)	10-Year Flood Urbanization Proj. (c.f.s.)	50-Year Flood Urbanization Exist. (c.f.s.)	50-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Exist. (c.f.s.)	100-Year Flood Urbanization Proj. (c.f.s.)	100-Year Flood Urbanization Tot. (c.f.s.)	500-Year Flood Urbanization Exist. (c.f.s.)	500-Year Flood Urbanization Proj. (c.f.s.)
Stream C												
Tait Hill Road	U/S	1.1	9,150	190	190	490	490	680	680	960	1,140	1,140
	D/S			80	80	120	120	140	140	150	160	160
Left-Bank Trib.	U/S	1.1	5,820	110	140	190	240	230	280	300	320	390
	D/S	1.4		170	270	320	470	400	580	600	600	790
Shields Street	U/S	1.6	1,840	220	370	460	680	580	830	850	850	1,160
	D/S			200	270	310	360	350	370	370	390	420
Mouth		1.7	0	210	290	330	380	360	410	420	420	470
Stream B												
Right-Bank Trib.	U/S	1.4	4,730	190	270	350	490	440	600	650	620	830
	D/S	2.1		250	370	510	690	640	840	960	940	1,190
Shields Street	U/S	2.3	2,375	280	410	580	780	740	970	1,090	1,080	1,380
	D/S			190	220	280	300	310	390	450	540	660
Mouth		2.4	0	190	220	280	300	320	390	450	550	670

EFFECT OF ROAD STRUCTURES

Two modifications were made to the 100-year flood with projected urbanization model. The importance of the road and railroad structure routings on the hydrologic analysis of Fossil Creek was demonstrated by removing the routings from one model. The other 100-year flood with projected urbanization model assumed all road and railroad structures plugged, with over-road routings allowed. These discharges are presented in tables 15, 16, and 17.

The effect of road structures is variable, but, through most of the stream reaches, discharges for the 100-year flood increase considerably if the road structures are removed. Discharges are somewhat reduced if culverts are assumed plugged.

Of the 24 road and railroad structures that were modeled, one roadway embankment was assumed to fail. This roadway has an 84-inch corrugated metal pipe for Fossil Creek and is located approximately 800 feet north of Portner Reservoir. The 500-year existing, 500- and 100-year projected urbanized, and 500- and 100-year totally urbanized floods would cause the gravel road to be overtopped by 3 to 3.5 feet. Failure of the road embankments was assumed to occur if they were overtopped by more than 2 feet.

Table 15
Fossil Creek
Effect of Road Structures

Station		Drainage Ar (sq. mi.)	Distance from 'outh (feet)	100-Year Flood With Projected Urbanization: Road Structures W/Open Culverts	W/O Road Structures	Road Structures W/Plugged Culvert
				(discharges in c.f.s.)		
Taft Hill Road	U/S	0.7	66,610	350	350	350
	D/S			180		0
Shields Street	U/S	1.2	59,675	800	930	770
	D/S			740		740
Stream C	U/S	1.3	58,910	800	1,010	870
	D/S	3.0		1,200	2,120	940
Stream A	U/S	3.2	55,300	1,180	2,200	880
	D/S	9.8		2,330	5,190	900
Colo. & Southern RR	U/S	9.9	53,875	2,380	5,200	950
	D/S			2,300		0
U.S. Highway 287	U/S	10.0	51,435	2,290	5,180	200
	D/S			2,280		0
Mail Creek	U/S	11.0	40,620	2,590	5,330	960
	D/S	12.3		3,140	6,010	1,290
County Road	U/S	12.4	38,775	3,200	6,010	1,340
	D/S			3,190		1,290
Right-Bank Trib.	U/S	14.2*	29,900	3,550	6,240	1,990
	D/S	16.7*		5,080	7,280	4,370

Table 15 (Cont'd)
Fossil Creek
Effect of Road Structures

Station		Drainage Area (sq. mi.)	Distance from Mouth (feet)	100-Year Flood With Projected Urbanization: Road Structures W/Open Culverts	W/O Road Structures	Road Structures W/Plugged Culver
				(discharges in c.f.s.)		
Union Pacific RR	U/S	16.7*	29,620	5,080	7,280	4,370
	D/S			1,420		0
County Road	U/S	17.9	24,885	1,510	7,240	460
	D/S			1,390		0
Right-Bank Trib.	U/S	18.2*	12,990	1,390	6,640	90
	D/S	26.6*		2,130	7,920	2,070
Fossil Creek Dam	U/S	26.6*	12,620	2,130	7,920	2,070
	D/S			870	1,610	410
Mouth		29.1*	0	870	1,550	450

*Contributing Area

Table 16
Stream A
Effect of Road Structures

Station		Drainage Area (sq. mi.)	Distance from Trib Mouth (feet)	100-Year Flood With Projected Urbanization: Road Structures W/Open Culverts (discharges in c.f.s.)	W/O Road Structures	Road Structures W/Plugged Culver
Taft Hill Road	U/S	1.2	21,270	720	720	720
	D/S			70		0
Right-Bank Trib.	U/S	2.3	14,650	490	1,080	460
	D/S	3.1		860	1,440	820
Shields Street	U/S	3.1	13,850	1,010	1,590	970
	D/S			450		380
Colo. & Southern	U/S	3.5	13,010	470	1,720	390
RR	D/S			460		390
Colo. & Southern RR		3.6	10,035	520	1,700	380
County Road	U/S	3.6	9,610	520	1,700	380
	D/S			450		370
Stream B	U/S	3.7	7,850	470	1,720	370
	D/S	6.1		780	3,260	540
Colo. & Southern	U/S	6.6	4,370	1,210	3,440	1,010
RR	D/S			1,130		730
Colo. & Southern	U/S	6.7	1,045	1,150	3,400	680
RR	D/S			1,140		580
Mouth		6.7	0	1,140	3,400	530

Table 17
Streams C and B
Effect of Road Structures

Stream	Station		Drainage Area (sq. mi.)	Distance from Trib. Mouth (feet)	100-Year Flood With Projected Urbanizatio: Road Structures W/Open Culverts (discharges in c.f.s.)	W/O Road Structures	Road Structure W/Plugged Culve
Stream C	Taft Hill Road	U/S	1.1	9,150	680	680	680
		D/S			140		0
	Left-Bank Trib.	U/S	1.2	5,820	280	760	250
		D/S	1.4		580	1,030	540
	Shields Street	U/S	1.6	1,840	830	1,130	800
		D/S			370		0
	Mouth		1.7	0	410	1,180	160
Stream B	Right-Bank Trib.	U/S	1.4	4,730	600	1,110	510
		D/S	2.1		840	1,520	730
	Shields Street	U/S	2.3	2,375	970	1,610	860
		D/S			390		210
	Mouth		2.4	0	390	1,650	210

Sheep Draw Hydrology

GENERAL

This section describes hydrologic studies for the Sheep Draw basin. Sheep Draw is a tributary of the Cache la Poudre River and is located west of Greeley. Discharges for the 10-, 50-, 100-, and 500-year floods were developed for existing and projected urbanized land use conditions.

BASIN DESCRIPTION

Sheep Draw, a right-bank tributary to the Cache la Poudre River, has its source near the U.S. Highway 34-Colorado Highway 257 intersection 8 miles west of Greeley, Colorado. From its source, Sheep Draw flows in a general northeasterly direction to business route U.S. Highway 34, then north to its confluence with the Cache la Poudre River. The 15-square-mile basin is primarily rural but is expected to urbanize within the next few years. Elevations in the basin range from 4690 to 5050 feet above mean sea level. A map of the Sheep Draw basin is shown on plate 4.

EXISTING STRUCTURES

Four reservoirs were considered in the hydrologic analysis of the basin. One is on Sheep Draw in sec. 13, T. 5 N., R. 67 W., approximately 1 mile upstream from U.S. Highway 34. Two others are located on tributaries in section 13. Another reservoir is on a tributary in sec. 4, T. 5 N., R. 66 W., approximately 1 mile upstream from the mouth of Sheep Draw. During late spring and summer, water from these reservoirs is used to irrigate nearby cropland. Although flood control is not a

specific function of these reservoirs, some residual flood control effects are provided downstream. Two canals, Boomerang Ditch and the North Boomerang Extension, are siphoned under Sheep Draw. These crossings have no effect on discharges along Sheep Draw. The canals are capable of intercepting some overland runoff in the basin, but it is difficult to predict where this will occur. Equally difficult to predict are points of failure along the canals. A good possibility exists that these canals would be full at the beginning of a major flood event. For these reasons, the canals were not included in the detailed hydrologic analysis of Sheep Draw. All pertinent highway and county road structures were evaluated for their flood storage effects. Reservoir routings utilizing storage-discharge curves were made for 13 of these structures.

MODELING STUDIES

GENERAL

The SWMM computer program was used to model rainfall-runoff characteristics of the Sheep Draw basin. Storms varying in frequency from 10 to 500 years were centered over the basin to obtain the flood discharges presented in this report. The SWMM model of the Sheep Draw basin contains 107 catchments, 80 streams, 13 road structures, and 4 dams. Basin characteristics for the model were taken from USGS 7.5-minute quadrangle mapping having a scale of 1:24,000 and a contour interval of 10 feet. Since the reservoirs are used for irrigation, it is not known if they will remain intact as the basin urbanizes. Therefore, hydrologic studies were made with and without the dams in place. Unless otherwise stated, the road structures were assumed in place with culverts open.

RAINFALL

Rainfall values for the 10-, 50-, and 100-year, 1-hour events were obtained from the Precipitation-Frequency Atlas of the Western United

States, Atlas 2, Volume III, Colorado, published by the NOAA in 1973. The 500-year value was estimated by extrapolating the selected 1-hour values on semilogarithmic paper. Adjustments for depth-area were based on the depth-area relationship presented in the NOAA publication. Adjustments for an average length of record of 40 years were made on logarithmic-probability paper using Beard's table of expected probability adjustments. The 1-hour rainfall distribution developed from NOAA criteria is given in table 18.

Table 18
1-Hour Rainfall Distribution

End of Period (minutes)	Incremental Rainfall (percent)
5	3
10	4
15	4
20	5
25	12
30	16
35	29
40	12
45	5
50	4
55	4
60	2

LOSSES

Infiltration rates for the Sheep Draw basin were obtained from Soil Resources of Colorado, Region 2 - Larimer and Weld Counties, published in 1976 by the CSU Experiment Station, Fort Collins, and the SCS. A general soil map of Weld County used in conjunction with table 3 of the CSU publication lists ranges of infiltration permeabilities for each soil series. Table 19 contains the soil associations that were taken from the general soil map, the range of infiltration permeabilities at various depths for each soil series, and the infiltration rate that was used in the SWMM model.

Table 19
Infiltration Rates for Sheep Draw Basin

Soil Association	Soil Series	Depth (inches)	Permeability (inches/hour)	SWMM Infiltration Rate (inches/hour)
Olney-Kim-Otero	Olney	0-10	0.6 - 2.0	0.8
		10-20	0.6 - 2.0	
		20-30	0.6 - 6.0	
		30-60	2.0 - 6.0	
	Kim	0-60	0.6 - 2.0	
	Otero	0-60	6.0 - 20.0	
Weld-Colby	Weld	0-7	0.6 - 2.0	0.8
		7-30	0.2 - 0.6	
		30-60	0.6 - 2.0	
	Colby	0-60	0.6 - 2.0	

All but the upper 3 square miles of the Sheep Draw basin has the Olney-Kim-Otero soil association. An infiltration rate of 0.8 inch per hour was selected as being representative of the ranges given above. A value of 0.2 inch was used for detention storage on pervious and impervious areas.

LAND USE

The Sheep Draw basin is subject to future urban development from the city of Greeley. Changes in imperviousness that would result from land use changes will affect the runoff potential. To reflect the influence of changing development, three levels of urbanization were considered. Two of these urbanization levels, existing and projected, are shown in the report Larimer-Weld Region Land Use Alternatives prepared for the Larimer-Weld Regional Council of Governments in November, 1977. The existing urbanization condition reflects no significant development. Projected urbanization is based upon year 2000 land use and is an intermediate level of development. Total urbanization assumes the entire basin is urbanized.

Existing and future urbanization are shown on plate 5. The land use patterns were slightly altered to fit hydrologic subareas in the SWMM model.

Any changes in these land use projections and future urbanization boundaries would change the hydrologic and hydraulic data presented in this study.

The percent of imperviousness of each catchment was estimated for existing, projected urbanized, and total urbanization conditions. Table 20 lists the percent of imperviousness for each land use that was considered in the model.

Table 20
Percent Imperviousness For Land Uses
In The Sheep Draw Basin

Land Use	Impervious Area (percent)
Commercial	90
Medium Density Residential	40
Agricultural	5

DISCHARGE-PROBABILITY RELATIONSHIPS

The 10-, 50-, 100-, and 500-year flood discharges for existing, projected, and total levels of urbanization are presented with and without the dams in place in tables 21 and 22, respectively.

Table 21
Sheep Draw
Discharge-Probability Relationships With Dams
(Discharges in c.f.s.)

Station		Drainage Area (sq. mi.)	Distance from Mouth (feet)	10-Year Flood Urbanization			50-Year Flood Urbanization			100-Year Flood Urbanization			500-Year Flood Urbanization		
				Exist.	Proj.	Tot.	Exist.	Proj.	Tot.	Exist.	Proj.	Tot.	Exist.	Proj.	Tot.
Streams 68 & 71	U/S	0.9	39,400	60	60	400	230	230	610	350	350	740	570	570	1,180
	D/S	2.2		250	250	1,090	730	730	1,760	1,050	1,050	2,170	1,790	1,790	3,410
Stream 62	U/S	2.4	36,450	270	270	1,110	770	770	1,880	1,110	1,110	2,310	1,930	1,930	3,630
	D/S	3.0		360	360	1,420	1,010	1,010	2,450	1,440	1,440	3,020	2,520	2,520	4,720
Streams 56 & 59	U/S	3.0	34,800	370	370	1,430	1,020	1,020	2,480	1,450	1,450	3,050	2,560	2,560	4,770
	D/S	4.2		540	540	2,050	1,450	1,450	3,640	2,050	2,050	4,480	3,650	3,650	6,940
Dam	U/S	4.2	34,650	540	540	2,050	1,450	1,450	3,640	2,050	2,050	4,480	3,650	3,650	6,940
	D/S	4.2		440	440	1,940	1,400	1,400	3,560	2,020	2,020	4,400	3,620	3,620	6,840
Stream 51	U/S	4.2	33,250	450	450	1,870	1,390	1,390	3,530	2,010	2,010	4,380	3,630	3,630	6,840
	D/S	4.8		470	470	1,880	1,450	1,450	3,640	2,110	2,110	4,750	4,190	4,190	7,890
Highway 34	U/S	5.4	29,490	490	490	1,870	1,530	1,530	3,810	2,240	2,240	5,010	4,480	4,480	8,370
	D/S	5.4		490	490	1,630	1,410	1,410	3,810	2,230	2,230	5,000	4,470	4,470	8,330
County Road 25	U/S	5.9	28,950	520	530	1,710	1,500	1,510	4,080	2,370	2,380	5,320	4,770	4,790	8,890
	D/S	5.9		520	530	1,690	1,450	1,460	4,080	2,370	2,380	5,320	4,770	4,790	8,890
Stream 38	U/S	5.9	28,900	520	530	1,690	1,450	1,460	4,080	2,370	2,380	5,320	4,770	4,790	8,890
	D/S	7.2		530	540	1,890	1,700	1,760	4,960	2,660	2,740	6,650	5,910	6,660	11,160
Stream 23	U/S	9.3	18,610	610	1,070	1,930	1,910	1,980	4,970	2,850	2,940	6,740	6,220	6,430	11,690
	D/S	10.3		630	1,210	1,970	1,950	2,250	5,060	2,920	3,010	6,860	6,350	6,560	11,900
Stream 20	U/S	10.9	14,400	650	1,290	1,940	1,980	2,440	4,930	2,930	3,090	6,650	6,300	6,490	11,620
	D/S	12.0		710	1,810	2,030	2,120	3,370	5,210	3,170	4,340	7,050	6,780	6,920	12,810
Streams 17, 13, & 72	U/S	12.1	12,640	710	1,830	2,020	2,120	3,400	5,160	3,170	4,310	6,990	6,750	6,900	12,660
	D/S	13.4		780	2,400	2,510	2,260	4,480	5,420	3,410	5,530	7,360	7,290	8,360	13,540
Stream 2	U/S	14.4	4,690	840	2,220	2,390	2,300	4,350	5,330	3,460	5,520	7,220	7,260	8,710	13,160
	D/S	14.6		860	2,260	2,420	2,320	4,420	5,380	3,500	5,610	7,270	7,310	8,840	13,230
Mouth		15.0	0	880	2,090	2,260	2,320	4,000	5,240	3,460	5,080	7,000	7,080	8,230	12,490

Table 22
Sheep Draw
Discharge-Probability Relationships Without Dams
(Discharges in c.f.s.)

Station		Drainage Area (sq. mi.)	Distance from Mouth (feet)	10-Year Flood Urbanization Exist.	10-Year Flood Urbanization Proj.	10-Year Flood Urbanization Tot.	50-Year Flood Urbanization Exist.	50-Year Flood Urbanization Proj.	50-Year Flood Urbanization Tot.	100-Year Flood Urbanization Exist.	100-Year Flood Urbanization Proj.	100-Year Flood Urbanization Tot.	500-Year Flood Urbanization Exist.	500-Year Flood Urbanization Proj.	500-Year Flood Urbanization Tot.
Streams 68 & 71	U/S	0.9	39,400	60	60	400	230	230	610	350	350	740	570	570	1,180
	D/S	2.2		250	250	1,090	730	730	1,760	1,050	1,050	2,170	1,790	1,790	3,410
Stream 62	U/S	2.4	36,450	270	270	1,110	770	770	1,880	1,110	1,110	2,310	1,930	1,930	3,630
	D/S	3.0		360	360	1,420	1,010	1,010	2,450	1,440	1,440	3,020	2,520	2,520	4,720
Streams 56 & 59	U/S	3.0	34,800	370	370	1,430	1,020	1,020	2,480	1,450	1,450	3,050	2,560	2,560	4,770
	D/S	4.2		540	540	2,050	1,450	1,450	3,640	2,050	2,050	4,480	3,650	3,650	6,940
Stream 51	U/S	4.2	33,250	550	550	2,040	1,460	1,460	3,640	2,050	2,050	4,480	3,670	3,670	6,950
	D/S	4.8		670	670	2,340	1,750	1,750	4,240	2,450	2,450	5,240	4,390	4,390	8,150
Highway 34	U/S	5.4	29,490	720	720	2,470	1,940	1,940	4,560	2,690	2,690	5,670	4,860	4,860	8,870
	D/S	5.4		720	720	2,460	1,830	1,830	4,560	2,690	2,690	5,660	4,850	4,850	8,860
County Road 25	U/S	5.9	28,950	770	790	2,650	1,950	1,960	4,900	2,910	2,960	6,090	5,210	5,270	9,530
	D/S	5.9		760	780	2,650	1,950	1,960	4,900	2,910	2,960	6,090	5,210	5,270	9,530
Stream 38	U/S	5.9	[illegible]	760	[illegible]	2,650	1,950	1,960	4,900	2,910	2,960	6,090	5,210	5,270	9,530
	D/S	7.2		960	1,040	3,030	2,330	2,410	6,170	3,650	3,820	7,650	6,610	6,690	11,980
Stream 23	U/S	9.3	[illegible]	1,040	1,230	3,040	2,560	2,820	6,520	3,800	4,140	8,270	7,310	7,710	13,170
	D/S	10.3		1,070	1,310	3,090	2,630	2,890	6,660	3,890	4,230	8,440	7,490	7,890	13,450
Stream 20	U/S	10.9	14,400	1,070	1,390	3,010	2,670	2,960	6,430	3,880	4,250	8,200	7,450	7,920	13,190
	D/S	12.0		1,150	1,860	3,180	2,870	3,500	6,880	4,170	4,570	8,780	8,040	9,060	14,600
Streams 17, 13, & 72	U/S	12.1	12,640	1,150	1,870	3,170	2,880	3,540	6,820	4,150	4,560	8,730	8,030	8,980	14,570
	D/S	13.4		1,240	2,420	3,330	3,110	4,560	7,240	4,470	5,620	9,290	8,750	9,870	15,660
Stream 2	U/S	14.4	4,690	1,270	2,270	3,270	3,160	4,500	7,000	4,470	5,680	9,020	8,690	10,030	15,290
	D/S	14.6		1,280	2,320	3,290	3,190	4,570	7,040	4,510	5,760	9,070	8,750	10,100	15,360
Mouth		15.0	0	1,280	2,160	3,150	3,120	4,240	6,600	4,350	5,390	8,470	8,320	9,800	14,220

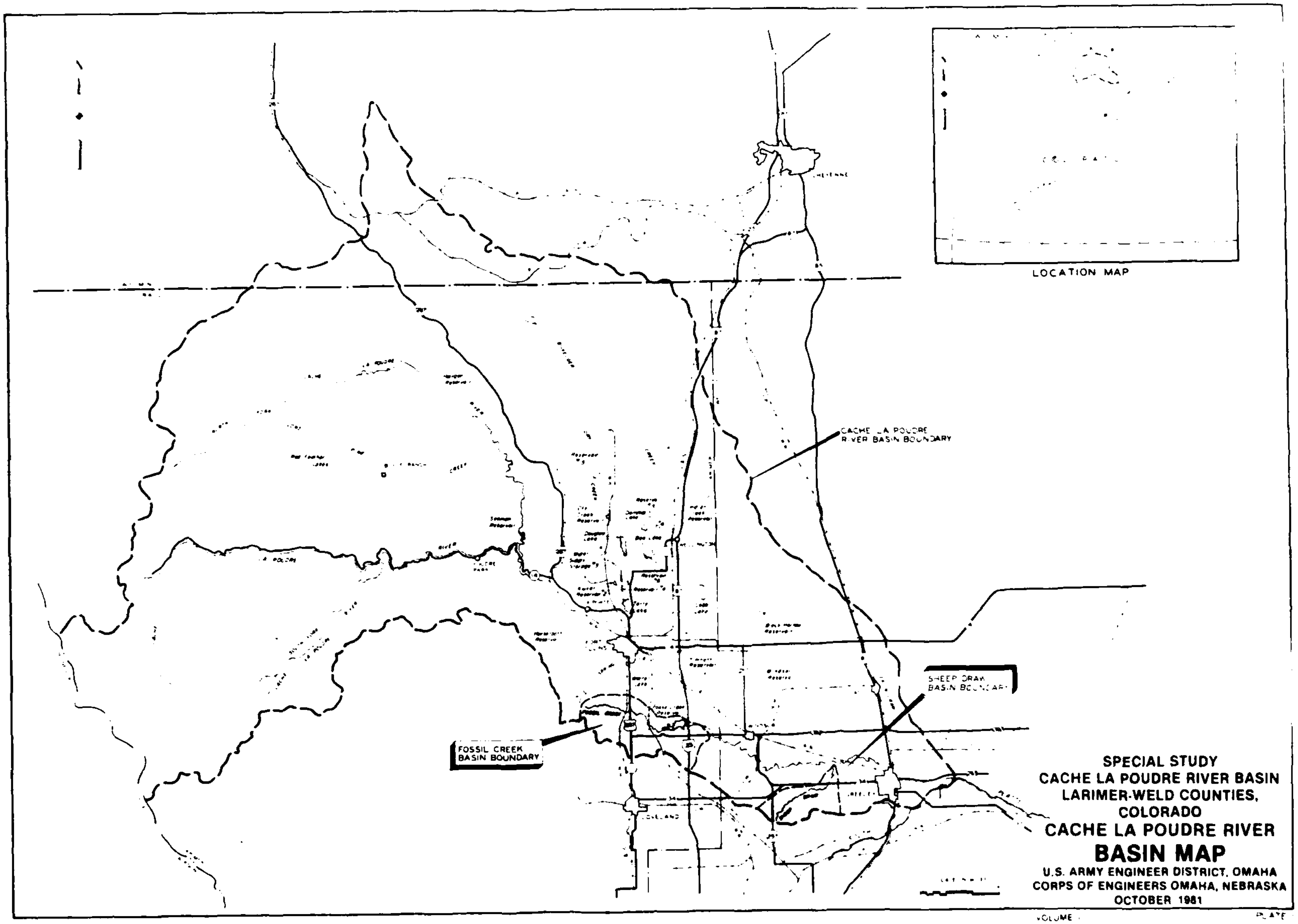
EFFECT OF ROAD STRUCTURES

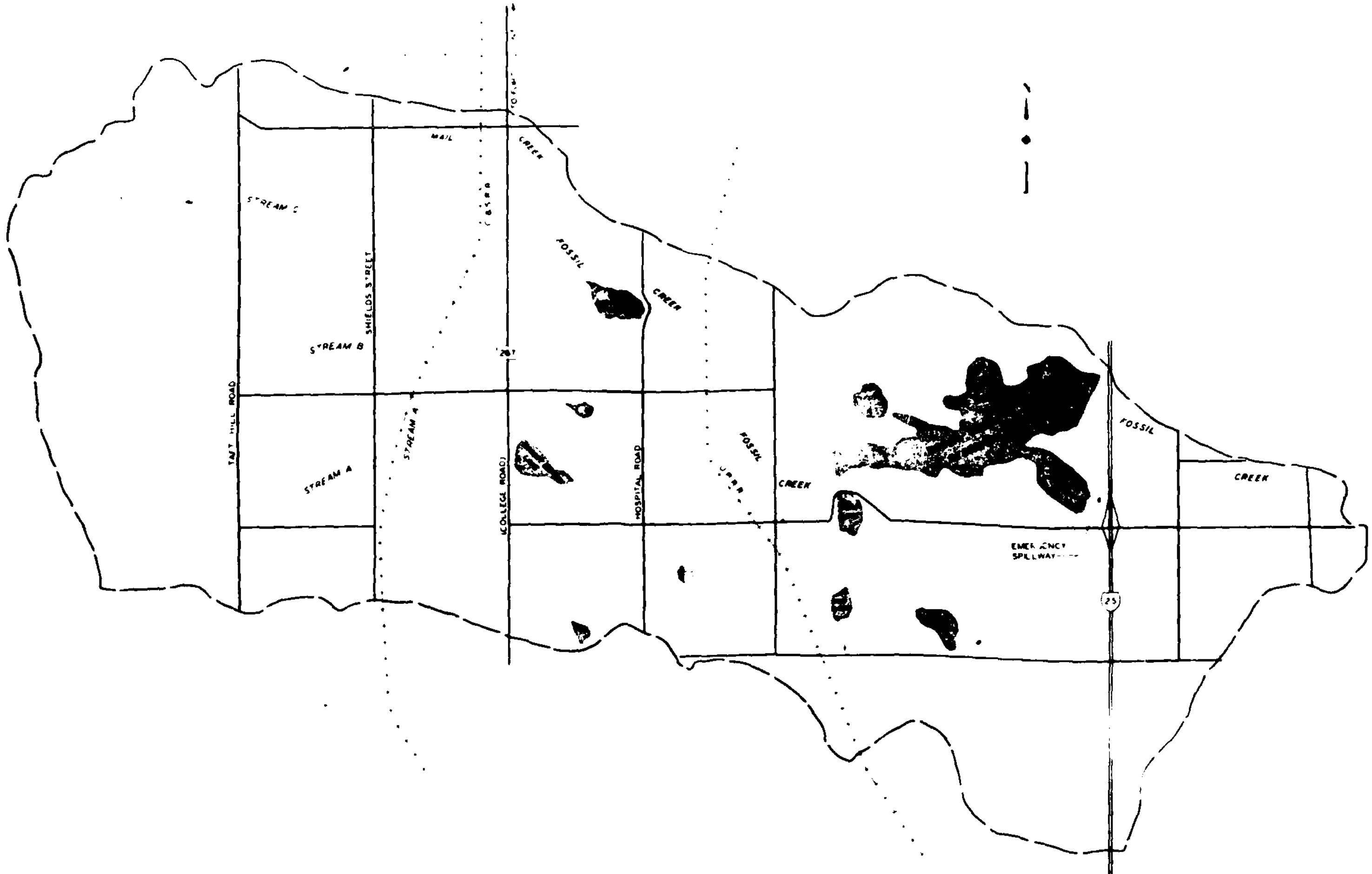
The preceding discharge-probability relationships for the Sheep Draw basin were developed with and without the dams in place. Road structures were assumed in place with culverts considered to be unobstructed. The 100-year flood under existing conditions was also modeled with roads removed to illustrate the effect of the road structures on discharge potential. The 100-year flood discharges with roads and dams in place, with dams removed, and with both roads and dams removed are shown in table 23. The removal of road structures increases discharges somewhat. The removal of the dams would increase discharges to a generally comparable degree.

Of the thirteen road structures and four dams that were modeled, two roadway embankments were assumed to fail. County Road 25 over Sheep Draw which has a 14-foot-by-6-foot concrete box culvert was assumed to fail with the 500- and 100-year existing, projected urbanized, and total urbanization conditions with and without dams; the 50-year total urbanization condition with and without dams; and the 10-year total urbanization condition without dams. County Road 25 also has a 24-inch corrugated metal pipe located 2,200 feet south of Highway 34. This roadway was assumed to fail at this location for the 500-year flood with existing and projected urbanized conditions without dams and with the 500-, 100-, and 50-year total urbanized conditions with and without dams. Failure of the road embankments was assumed to occur if they were overtopped by more than 2 feet.

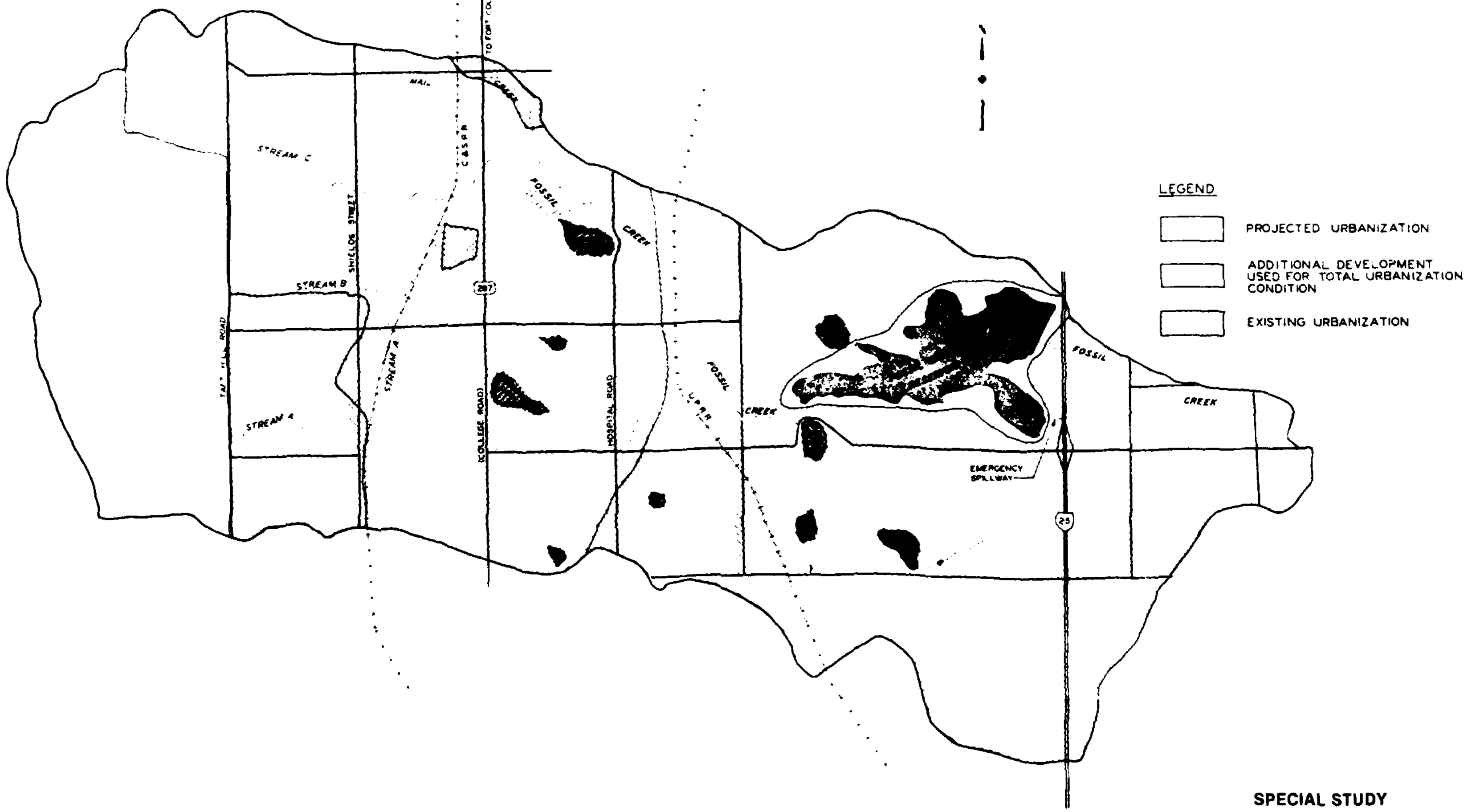
Table 23
Sheep Draw
Effect of Road Structures

Station		Drainage Area (sq. mi.)	Distance from Mouth (feet)	100-Year Flood With Existing Urbanization (discharges in c.f.s.)		
				W/Road Structures & W/Dams	W/Road Structures & W/O Dams	W/O Road Structures & W/O Dams
Streams 68 & 71	U/S	0.9	39,400	350	350	390
	D/S	2.2		1,050	1,050	1,100
Stream 62	U/S	2.4	36,450	1,110	1,110	1,180
	D/S	3.0		1,440	1,440	1,520
Streams 56 & 59	U/S	3.0	34,800	1,450	1,450	1,540
	D/S	4.2		2,050	2,050	2,150
Stream 51	U/S	4.2	33,250	2,010	2,050	2,160
	D/S	4.8		2,110	2,450	2,570
Highway 34	U/S	5.4	29,490	2,240	2,690	2,820
	D/S	5.4		2,230	2,690	2,820
County Road 25	U/S	5.9	28,950	2,370	2,910	3,030
	D/S	5.9		2,370	2,910	3,030
Stream 38	U/S	5.9	28,900	2,370	2,910	3,030
	D/S	7.2		2,660	3,650	3,800
Stream 23	U/S	9.3	18,610	2,850	3,800	4,270
	D/S	10.3		2,920	3,890	4,600
Stream 20	U/S	10.9	14,400	2,930	3,880	4,600
	D/S	12.0		3,170	4,170	4,940
Streams 17, 13, & 72	U/S	12.1	12,640	3,170	4,150	4,920
	D/S	13.4		3,410	4,470	5,400
Stream 2	U/S	14.4	4,690	3,460	4,470	5,390
	D/S	14.6		3,500	4,510	5,420
Mouth		15.0	0	3,460	4,350	5,180


LOCATION MAP
CACHE LA POUDRE
RIVER BASIN BOUNDARY
SHEEP DRAW
BASIN BOUNDARY
FOSSIL CREEK
BASIN BOUNDARY
SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES,
COLORADO
CACHE LA POUDRE RIVER
BASIN MAP
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCTOBER 1981
VOLUME
PLATE



SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO
FOSSIL CREEK
BASIN MAP
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCTOBER 1981



SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO
FOSSIL CREEK
FUTURE URBANIZATION
U.S. ARMY ENGINEER DISTRICT, OMAHA
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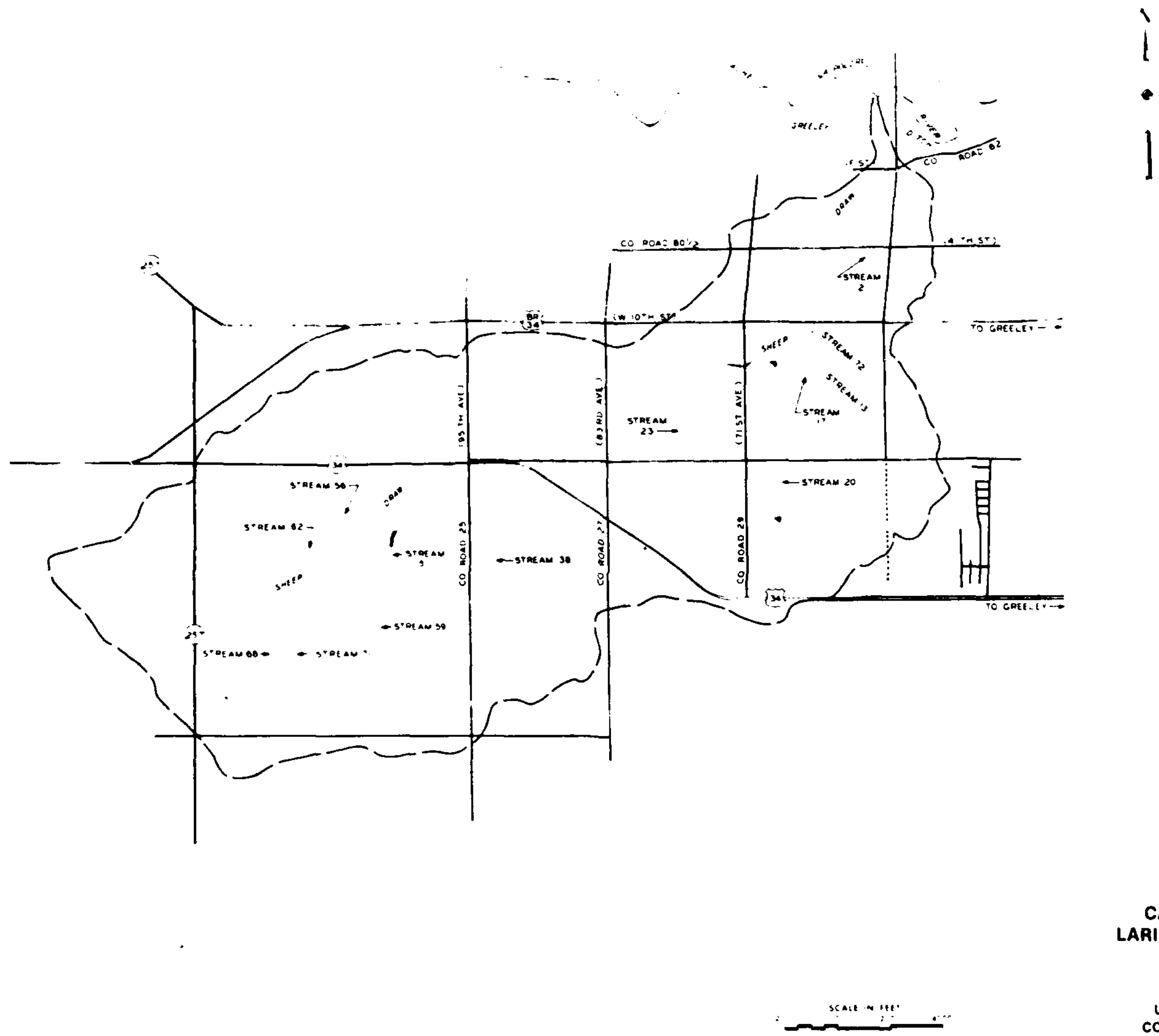
OCTOBER 1981

VOLUME II PLATE 3



SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO

SHEEP DRAW
BASIN MAP

U.S. ARMY ENGINEER DISTRICT, OMAHA
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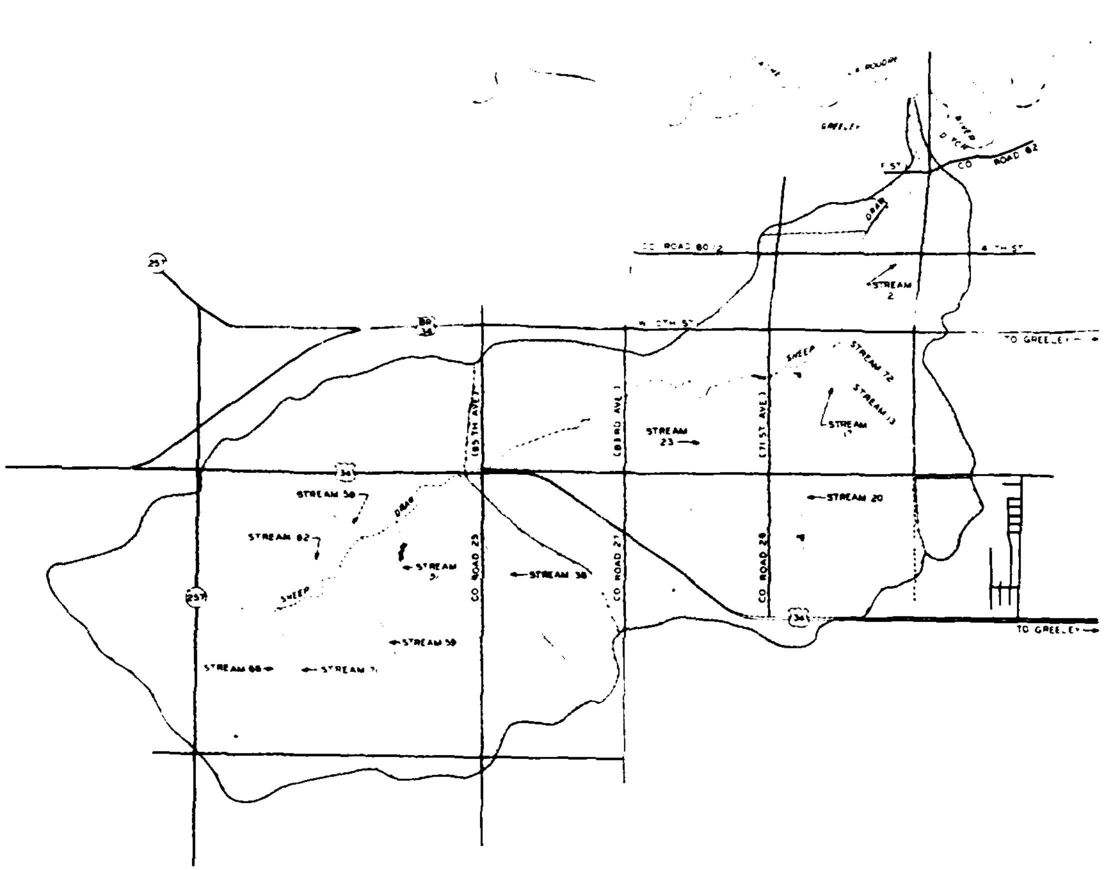
OCTOBER 1981

VOLUME II



LEGEND

PROJECTED URBANIZATION

ADDITIONAL DEVELOPMENT USED FOR TOTAL URBANIZATION CONDITION

SPECIAL STUDY
CACHE LA POUDRE RIVER BASIN
LARIMER-WELD COUNTIES, COLORADO
SHEEP DRAW
FUTURE URBANIZATION
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
OCTOBER 1981

APPENDIX A
GLOSSARY

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Annual Peak Discharge

The maximum instantaneous stream discharge that occurs during the year at a given location. In most cases it is determined by comparing the highest stage recorded during the year to a stage-discharge relationship which has been established for the stream at the particular location. During extreme events, it is usually based on a slope-area analysis of the high water marks.

Beard's Statistical Method

This is an analytical method based on a log-Pearson type III distribution similar to that presented in the Water Resources Council (WRC) Bulletin 17. The only difference in the two approaches as they pertain to this study was the selection of the skew coefficient. The Beard's method uses either zero skew or a regional skew. The WRC method weights the station skew with an appropriate generalized skew.

Catchment

A drainage area. In this report this refers to the small subareas used to divide up larger drainage areas. In preparing data to be entered into a hydrologic model, a large drainage area may be subdivided to better reflect variations in soil, soil cover, and topography.

Confidence Limits

A measure of reliability of the frequency curve discharge values. The confidence range as shown varies from .05 to .95. This means that at a given return frequency, there is a 95-percent chance that the true return discharge exceeds the lower limit and only a 5-percent chance that it exceeds the upper limit.

Contributing Area

That portion of a drainage area that contributes to runoff at a given point. Runoff may not occur from parts of a drainage area due to dams, pothole areas that have no outlet, or pervious soils with high infiltration rates.

Depth-Area Adjustment

As the drainage areas become larger, the average depth of rainfall over the basin becomes smaller at any given return frequency. An adjustment based on an empirical relationship developed by the National Oceanic and Atmospheric Administration was made to all rainfall values used in the study to compensate for this natural phenomenon.

Detention Storage

The amount of rainfall and/or rainfall runoff which is intercepted by ditches, ponds, or natural depressions and is therefore removed from the normal surface-runoff pattern.

Discharge-Probability Relationship

The chances (see "Probability") of floods of different magnitudes occurring at a given location. Smaller floods are likely to occur more often, while greater floods are less common.

Exceedence Frequency

The likelihood of an event with a given magnitude being equalled or exceeded in any given year.

Expected Probability

An adjustment for the skewed distribution of the sample error around the true population.

Frequency

(See "Probability")

Hydrograph

A graph or table showing the variation of discharge over a period of time at a given location. A flood hydrograph would show a rise in discharge (ascension limb), a peak, and then a decrease in discharge (recession limb), gradually returning to normal levels.

Hydrologic Model

A series of mathematical relationships which takes into account factors affecting runoff from rainfall and which is used to make estimates of stream discharge based on the runoff volume and the delivery characteristics of the drainage area involved.

Hydrologic Studies

In this report, this refers to studies to determine the discharge-probability relationship at various locations or to determine Probable Maximum Flood hydrographs at damsites to evaluate their hydrologic capability during extreme flood events.

Hyetograph

A graphical representation of the distribution of rainfall with respect to time.

Imperviousness

The degree to which an area will shed water and not allow rainfall to penetrate. For example, paved areas are essentially impervious, while sandy areas are very pervious.

Infiltration

Precipitation soaking into the ground. For example, a sandy soil may absorb a great deal of rainfall without leaving an excess for surface runoff. This may be expressed as the total proportion of rainfall absorbed or as an infiltration rate in inches per hour (see "Runoff").

Log-Pearson Type III

A mathematical expression that experience has demonstrated provides the best representation of the distribution of flood events as they occur in nature.

Mean Flood

The mean flood is an event that has a 50-percent chance of being equalled or exceeded in any given year. Or, in other words, it would be expected that half the annual peak discharges at a given location would be higher in magnitude while the other half would be lower.

MITCAT

Massachusetts Institute of Technology Catchment Model—one of several computer programs that can be used as a hydrologic model.

Modified Puls Method

A channel flood routing procedure which is based on the computed or estimated storage-discharge relationship for a given reach of the river or stream. This procedure can also be used to flood route through reservoirs.

N

Actual number or an equivalent number of years in a discharge record.

Noncoincident

Flood events or tributary inflows that have peaking times that are not synchronized.

Normal Distribution

A normal distribution is a mathematical distribution that is commonly referred to as the "bell shaped" curve. A log-Pearson type III curve has a normal distribution when the skew coefficient is equal to zero.

Overland Flow Length

An idealized estimate of the average length of the overland flow distance that runoff water will travel to get to a stream or channel in a hydrologic model subarea.

Partial Duration

Denotes the type of discharge-frequency analysis. An annual series curve is based on using a single momentary maximum event each year. A partial duration series considers all peaks above a given base.

Peak Discharge

The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest. In the graphical representation of flow versus time, which is known as a flood hydrograph, the peak discharge occurs between the ascension limb and the recession limb.

Peaking Time

The lag time from the start of a runoff-producing rainfall to the time the flood reaches its maximum discharge.

Probability

The annual chance of occurrence of specific hydrologic events, such as rainfall, over a specified area or peak discharge at a specified location expressed in percent, e.g., 5 percent representing one chance in 20 of the event occurring in any year. The 10-, 50-, 100-, and 500-year floods are floods having a 10-, 2-, 1-, or .2-percent probability, respectively, of occurrence in any year or an average recurrence interval in the order of once in 10, 50, 100, or 500 years, respectively. It may be based on statistical analyses of streamflow records and/or the analyses of rainfall and runoff characteristics in the general region of the watershed.

Rainfall Distribution

(See "Hyetograph")

Reservoir Routings

A study of the relationship between flood inflow to a reservoir and the resulting controlled and uncontrolled outflow from the reservoir. If there is insufficient storage volume and controlled releases cannot be made fast enough through an outlet works and/or the emergency spillway, the dam embankment or structure will be overtopped.

Runoff

The quantity of rainfall which flows over the surface to enter the stream as discharge volume. The difference in quantity between rainfall and runoff represents losses to infiltration, detention storage, and evapo-transpiration.

S

This represents the standard deviation of the logarithm of the flows, which is the second moment in the statistical analysis of a flow record. It is a statistical measure of the range of variation of flows around the mean flood.

SCS Curve No.

The curve number represents a specific rainfall-runoff relationship which is based on the cover-complex in the basin being studied.

Skew

Skew is the third moment in a statistical analysis of a flow record. It is a statistical measure of the deviation of the distribution away from the normal "bell shaped" curve.

Snyder's Constants

These constants are used in empirical relationships to develop a unit hydrograph for a drainage basin. The constants affect the magnitude of the peak and the peaking time of the unit hydrograph.

Standard Deviation

(See "S")

Stream Gage

A device to indicate the water depth of a stream at the gage site. The discharge at this location can be determined by using the stage or water level measured by the gage and comparing it to a stage-discharge relationship which has been established for that stream at the stream gage location.

SWMM

Environmental Protection Agency's Storm Water Management Model--one of several computer programs that can be used as a hydrologic model.

Synthetic Unit Hydrograph

A unit hydrograph is a hydrograph representing 1 inch of runoff from a given basin. The desirable method of determining a unit graph for a basin is from a recorded flood event with runoff approaching 1 inch or more. However, in most instances, these data are not available; therefore, a "synthetic" unit hydrograph based on an empirical relationship (See Snyder's Constants) is used.

Weibull Plotting Position

A procedure for determining the relative frequency of each flood event recorded during a given period of record.

WRC Frequency Analysis

A statistical analysis of a streamflow record based on the procedures outlined in the Water Resources Council publication Bulletin No. 17.

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